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Public Health England

Indicators to assess the resilience of health and emergency planning in England to the projected impacts of climate change

Final report

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Executive Summary

The Adaptation Sub-Committee (ASC) of the Committee on Climate Change has a statutory duty to report to Parliament with an independent assessment of the UK Government's progress in implementing its National Adaptation Programme. In order to make its assessment of progress, the ASC is producing a series of annual progress reports that assess preparedness for the main risks and opportunities facing the UK from climate change, as identified by the UK Climate Change Risk Assessment.

The 2014 report, to be published later this year will include analysis of the preparedness of health and emergency planning, infrastructure and business to the projected impacts of climate change. As a result, there is a prior requirement for the development of indicators that can monitor changes over time under each of these categories. This report, prepared by HR Wallingford and Public Health England, considers indicators that have been identified under the health and emergency planning category for England for the 2014 progress report. This has considered the level of preparedness under this category for four themes; overheating, emergency planning and social equity, as well as other climate-related risks to health.

As a result of discussions with the ASC and sector experts, twenty-two indicators have therefore been assessed in this report. The choice of indicators has been based on those which have freely and readily available datasets, the applicability of the indicator to assessing preparedness for climate change, and ease of assessment. The final list of indicators is not comprehensive but reflects those indicators that are relevant and can be updated in the future. These have been considered under four different categories of risk, namely exposure, vulnerability, actions and impacts. Where possible, these have been assessed as a time series, although for some datasets, only single snapshots in time were possible, with the potential for time series to be considered in future years when more data is available.

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1. Introduction

The Adaptation Sub-Committee (ASC) of the Committee on Climate Change has a statutory duty to report to Parliament with an independent assessment of the UK Government's progress in implementing its National Adaptation Programme. In order to make its assessment of progress, the ASC is producing a series of annual progress reports that assess preparedness for the main risks and opportunities facing England from climate change, as identified by the UK Climate Change Risk Assessment. So far, four reports have been completed which are:

1. 2010 – How well prepared is the UK for climate change?
2. 2011 – Adapting to climate change in the UK: Measuring progress.
3. 2012 – Climate change – is the UK preparing for flooding and water scarcity?
4. 2013 – Managing the land in a changing climate.

The next report published this year will include analysis of the preparedness of health and emergency planning, infrastructure and business to the projected impacts of climate change.

As part of this assessment, there is a prior requirement for the development of indicators that can monitor changes over time in preparedness. These indicators fall into three broad categories, which are:

- Indicators of risk - Measure changes in the **exposure**[1] and **vulnerability**[2] of the sector to the weather;
- Indicators of adaptation **action** - Aim to measure the extent of actions to reduce risks from climate change;
- Indicators of climate **impacts** - Track the realised impacts of weather on the economy, society and the environment.

To develop these indicators, in September 2013, the ASC therefore commissioned HR Wallingford and Public Health England to assess indicators in health and emergency planning (subsequently referred to as the "health theme"). This report outlines the results of this assessment, and provides part of the supporting evidence for the ASC's 2014 annual report. In addition, this report should be read in conjunction with the parallel report on infrastructure (HR Wallingford, 2014), which has assessed indicators of interest to this report, including exposure and criticality of hospitals, care homes, GPs, schools and emergency services.

[1] The extent to which a recipient (people, livelihoods, infrastructure, economic/social/cultural/environmental assets) comes into contact with a climate impact.

[2] The degree to which a recipient is affected, either positively or negatively, by exposure to a climate hazard. This includes the ability of the recipient to prepare, respond and recover from a climate hazard or benefit from a positive impact.

2. Indicators

2.1. Introduction

Under the health and emergency planning theme for the ASC's 2014 progress report, there is a focus on four sub-themes in assessing the level of preparedness, under the categories of exposure, vulnerability, actions and impacts. These are:

- **Overheating** - responding to overheating risks, both through cooling measures in buildings and transport infrastructure, and other measures e.g. changing behaviour, warning systems, implementation of measures to protect vulnerable people at the local level.
- **Emergency planning** - responding in a coordinated fashion to extreme weather events such as flooding or storms. This includes the actions of the emergency services and appropriate contingency planning at the local authority level.
- **Social equity** - protecting the most vulnerable in society to the health and wellbeing-related risks from climate change. This includes what specific measures are being taken to protect the elderly, very young, those with illnesses, and people from lower socio-economic groups.
- **Other climate-related risks to health** - responding to other potential risks where the scale of threat from climate change is very difficult to quantify. This relates to risks where there is a complex interaction between climate and socio-economic factors in determining how exposure and vulnerability will change in the future. This includes mortality/morbidity from air pollution, aeroallergens, storms and UV/sunshine. An important part of this section of the analysis will be to determine to what extent action is justified, taking into account the uncertainties in future risk.

Following the start-up meeting with the ASC in September 2013, sixty-two potential indicators and data sources were identified across these four categories. From further discussions, these were later expanded to seventy-nine, and these formed the basis of an interim report published in early November 2013, HR Wallingford (2013). This report outlined a proposed methodology to assess each indicator, as well as potential data sources, accounting for a key requirement of the project; that the assessment of the indicators should be repeatable, and based on freely and readily available data sets.

The report was issued to selected relevant sector experts (see Appendix A), and a meeting held with them in mid-November 2013 to discuss the appropriateness of each indicator and potential sources of data, as well as any other relevant indicators. As a result of this meeting and subsequent discussions with the ASC, four further indicators were added to this list, giving a grand total of eighty-three potential indicators[3]. However, at this meeting, and with subsequent discussions with the ASC, a number of the indicators or assessment of them was not considered suitable. Typically this was because they were not a suitable indicator due to problems with the underlying data or because they were not a good measure of risk or action, or suitable data was not freely and readily available.

The size of this contract allowed for analysis to be conducted for about 20 priority indicators. A final list of eleven priority indicators was therefore agreed with the ASC in December 2013. In addition to this list of priority indicators eleven further indictors were later agreed based on available datasets and ease of assessment. The full list of the original eighty-three potential indicators are shown in Table 2.1, highlighting

[3] The original numbering system from the sector expert meeting in November 2013 has been maintained. The four additional indicators have therefore been added to Table 2.1 under the appropriate category of risk and indicator type, with an appropriate subscript (e.g. 35a) to maintain the unique numbering system.

the twenty-two indicators assessed in this report. For the indicators assessed, further details on how they have been assessed, the purpose and the data sources are given in Appendix B.

Table 2.1: Health and Emergency Planning Indictors

ID	Category of Risk	Indicator Type	Indicator Title	Assessed
1	Overheating	Exposure	Number of days the daily maximum and minimum temperature exceeds defined thresholds (see Armstrong, 2010).	√
2	Overheating	Exposure	Number of days the daily maximum temperature on the London Underground exceeds certain temperature thresholds.	
3	Overheating	Exposure	Trends in urban and rural temperature.	√
4	Overheating	Exposure	Number of heatwave alerts.	√
5	Overheating	Exposure	Area of urban greenspace and bluespace.	√
6	Overheating	Exposure	Number of hot and humid days per year.	
7	Overheating	Exposure / Vulnerability	Vulnerable people in urban areas.	√
8	Overheating	Vulnerability	Building types around the country.	√
9	Overheating	Vulnerability	Standard Assessment Procedure (SAP rating) - a measure of insulation in homes.	√
10	Overheating	Vulnerability	Indoor temperatures for different building types (homes, hospitals, care homes, schools, offices, commercial buildings etc.).	
11	Overheating	Vulnerability	Number of hospital admissions with cardiovascular illnesses.	
12	Overheating	Vulnerability	Number of hospital admissions with respiratory illnesses.	
13	Overheating	Vulnerability	Age distribution of population.	√
14	Overheating	Vulnerability	Number of people in at-risk occupation groups.	
15	Overheating	Vulnerability	Average time population spends indoors/outdoors.	
16	Overheating	Action	Uptake of cooling measures in buildings and transport (air conditioning etc.).	
17	Overheating	Action	Degree of ventilation in homes, offices, schools, hospitals and care homes.	
18	Overheating	Action	Uptake of changed working hours by businesses.	
19	Overheating	Action	Implementation of heatwave plans in care homes.	
20	Overheating	Action	Number of local authorities implementing/monitoring action plans for elderly during hot weather.	
21	Overheating	Action	How many older people are visited.	

ID	Category of Risk	Indicator Type	Indicator Title	Assessed
22	Overheating	Action	Buildings with passive cooling.	
23	Overheating	Action	Evidence that local authorities know where their vulnerable people are.	
24	Overheating	Action	Amount of monitoring of indoor temperatures.	
25	Overheating	Impact	Reduced productivity of workforce.	
26	Overheating	Impact	Number of heat-related deaths.	√
27	Overheating	Impact	Number of heat-related hospital admissions.	
28	Overheating	Impact	Number of heat-related hospital admissions (Asthma).	
29	Overheating	Impact	Levels of thermal discomfort in buildings/transport.	
30	Emergency planning	Exposure	Number of extreme weather events (trends in very wet days).	√
31	Emergency planning	Exposure	Severe weather warnings.	
32	Emergency planning	Vulnerability	Number of insurance claims for different extreme events.	
33	Emergency planning	Vulnerability	Number and location of vulnerable people that would need special assistance in the case of an extreme weather event.	√
34	Emergency planning	Vulnerability	Degree of spare capacity in hospitals currently (e.g. most are running at 90% for example so not a lot of redundancy in the system).	
35	Emergency planning	Action	Number of properties/people signed up to the Environment Agency's flood warning service.	√
35a	Emergency planning	Action	Number of properties/people at significant risk of flooding.	√
36	Emergency planning	Action	Community risk registers.	
37	Emergency planning	Action	Number of local authorities with emergency evacuation plans for vulnerable people.	
38	Emergency planning	Impact	Number of flood incidents attended by the fire service (as a percentage of total call outs).	√
39	Emergency planning	Impact	Financial losses from extreme weather events (for different sectors).	
40	Emergency planning	Impact	Number of working/school days lost from extreme events.	
41	Emergency planning	Impact	Time between flood event and people returning to their homes.	
42	Emergency planning	Impact	Numbers of deaths from flooding.	
43	Emergency planning	Impact	Homes without water/electricity due to a flood event.	

ID	Category of Risk	Indicator Type	Indicator Title	Assessed
44	Social equity	Vulnerability	Number of households/people from lower socio-economic groups living in areas at significant risk of flooding.	√
45	Social equity	Vulnerability	Number of at risk building types (caravans, basement flats) in areas at flood risk.	
46	Social equity	Vulnerability	People living alone	
46a	Social equity	Vulnerability	People living in Fuel Poverty	√
47	Social equity	Action	Number of hospitals with flood defences/heatwave plans.	
48	Social equity	Action	Number of care homes implementing flood plans/heatwave plans (repeated from overheating).	
49	Social equity	Action	Numbers of people accessing food banks.	
50	Social equity	Action	Number of households/businesses with flood insurance.	
51	Social equity	Impact	Deaths of people aged over 70 from extreme events.	
52	Social equity	Impact	Deaths of people in lower socio-economic groups from extreme weather events.	
53	Social equity	Impact	Number of adults with mental health impacts following a flood (note, there is no data for children).	
54	Other climate-related risks to health	Exposure	Concentrations of ground level Ozone (e.g. days with concentrations over a certain threshold).	√
55	Other climate-related risks to health	Exposure	Levels of indoor air pollutants.	
56	Other climate-related risks to health	Exposure	Flowering season timing for different allergenic plants	√
57	Other climate-related risks to health	Exposure	Pollen counts from Met. Office	
58	Other climate-related risks to health	Exposure	Storm frequency/magnitude.	
58a	Other climate-related risks to health	Exposure	Sea levels above 1990-1999 empirical 1 year level	√
59	Other climate-related risks to health	Exposure	Levels of indoor dampness/mould.	√
60	Other climate-related risks to health	Exposure	Area/length of coastal stretches with low water quality (based on Bathing Water Directive).	
61	Other climate-related risks to health	Exposure	Area/length of coastal stretches with low water quality (based on Water Framework Directive).	

ID	Category of Risk	Indicator Type	Indicator Title	Assessed
62	Other climate-related risks to health	Vulnerability	Number of people with respiratory illnesses (e.g. asthma, allergic rhinitis, emphysema).	
63	Other climate-related risks to health	Vulnerability	Average time population spends outdoors.	√
64	Other climate-related risks to health	Action	Public awareness campaigns on risks from UV/Sunshine.	
65	Other climate-related risks to health	Action	Deployment/uptake of warning systems.	
66	Other climate-related risks to health	Action	Air quality measures to reduce ozone, PM and NO2.	
67	Other climate-related risks to health	Action	Control measures for invasive plants.	
68	Other climate-related risks to health	Action	Degree of ventilation in homes, offices, schools, hospitals, care homes.	
69	Other climate-related risks to health	Action	Number of homes/schools/hospitals/offices monitored for indoor air quality.	
70	Other climate-related risks to health	Impact	Number of skin cancer cases.	
71	Other climate-related risks to health	Impact	UVR exposure	√
72	Other climate-related risks to health	Impact	Number of deaths from respiratory illnesses linked to air pollution.	
73	Other climate-related risks to health	Impact	Numbers of hospital admissions/GP visits for respiratory problems.	
74	Other climate-related risks to health	Impact	Number of deaths/injuries from storms.	
75	Other climate-related risks to health	Impact	Number of incidences of norovirus/vibrio, etc.	
75a	Other climate-related risks to health	Impact	Harmful algal blooms and jellyfish incidence	
76	Other climate-related risks to health	Impact	Ambulance calls (Percentage of Category A calls against temperature).	
77	Other climate-related risks to health	Impact	Ambulance calls (Percentage of respiratory calls against temperature).	
78	Other climate-related risks to health	Impact	Incidence of vector borne diseases	
79	Other climate-related risks to health	Impact	Food poisoning	

2.2. Assessment methodology

Although many indicators can be assessed simply, such as those where only a single dataset is required to assess an indicator, and this is only available in the form of national statistics, many indicators require a more sophisticated spatial assessment. This could include (for example) mapping vulnerable people against a climate risk such as temperature or flooding. As such, a method for developing spatial indicators of risk, action and impact was devised by HR Wallingford (2012) to provide evidence that fed into the ASC's third annual report, on preparedness for flooding and water scarcity. The method is based upon using, where appropriate, a Geographical Information System (GIS) to spatially pre-process data from robust, reliable and readily available sources of national scale data. Multiple layers of data on hazards (e.g. flooding) and receptors (e.g. number of assets) are then built up into a high- resolution spatial database. Queries can subsequently be efficiently run on the data and trends identified between different hazards, receptors and time periods. Typically, performing spatial comparison between a large number of mapping datasets can be very time consuming, particularly when processing very complex polygon data. As additional layers are added, it can become impractical due to increasing complexity of the unique combinations through all datasets. Due to the large number of very complex datasets and the national scale of the study area, this more efficient approach was developed and applied for the 2012 project and afterwards re-used for the 2013 assessment. The approach adopted is reliable, unbiased, repeatable, easily validated and can be efficiently extended in the future for new indicators or new snapshots in time.

Of the twenty-two indicators assessed in this report, about half have required the more sophisticated assessment outlined above, without which, they could not have been assessed.

3. Assessment of indicators

This section describes each of the indicators outlined for assessment in Table 2.1. For each indicator, any variation from the methodology from Section 2.2 is given, outlining the data sources used as well as any specific caveats.

Where considered appropriate, the most appropriate best fit or trend lines have been applied to the data. In addition to the best fit lines, data that are considered as outliers have also been identified. Any data considered as an outlier has been excluded from any trends identified in the data series.

It should be noted that much of the data available to be assessed is only available in certain formats. This includes for example data for Primary Care Trust and Strategic Health Authorities. Although in these cases, these no longer exist, the data is only available in these formats, so results can only be presented in this form.

3.1. Indicator 1: Number of days the daily maximum and minimum temperature exceeds defined thresholds

Introduction

Temperature variations, particularly extremes of hot and cold weather can have negative health impacts on the population, including an increase in mortality. The relationship between temperature and mortality tends to follow a U-shape relationship, with increased risk of heat-related mortality above a temperature threshold for heat effects, and similarly, an increased risk of cold-related mortality below a temperature threshold for cold effects. The shape of the relationship and the value of the hot and cold temperature thresholds vary by

population profile. Very few of these deaths arise as a direct result of hyperthermia or hypothermia, but rather from temperature effects on pre-existing disease, particularly cardiovascular and respiratory. This can lead to an increase in the number of deaths and hospital admissions in both the summer and winter months (this is discussed in more detail for heat-related deaths in Section 3.8).

This indicator assesses the number of days the daily maximum temperature exceeds the two-day average maximum temperature 93rd and 95th thresholds, as well as the number of days the daily minimum temperature is below the two-day average minimum temperature 10th threshold. This analysis and the thresholds are based on the data over the period 1993-2006 published in Hajat *et al.*, 2012, Hajat *et al.*, 2014 and Hames and Vardoulakis, 2012.

Methodology

To assess this indicator, maximum and minimum observed gridded daily temperature data was downloaded from the Met Office (National Climate Information Centre) website over the period 1960-2011 (see Perry and Hollis, 2006). This data, covering England at a 5 × 5 km resolution, was matched up to population data from the 2011 census to determine daily population weighted temperatures for each English region for daily maximum and minimum temperatures[4]. This data was then compared to the two-day average temperature thresholds determined from the data set published in Hajat *et al.*, 2012, Hajat *et al.*, 2014 and Hames and Vardoulakis (2012), see Table 3.1. This enabled the number of days the population-weighted daily maximum temperature was above, or daily minimum temperature was below these thresholds to be calculated. The two-day average maximum temperature thresholds (93rd and 95th percentile) were used to maintain consistency with previous published research based on these data sets. The two-day average minimum temperature threshold was used to maintain consistency with the analysis carried out for the maximum temperature analysis. The 10th threshold was chosen as this approximately coincided with temperature for all regions of between 0ºC (i.e. freezing conditions) to +2ºC, the cold threshold used in the Cold Weather Plan (Public Health England, 2013b). It should be noted that this is not the same as the threshold at which mortality starts to increase in each region, which is generally higher than 2ºC (see Hajat *et al.*, 2014).

Table 3.1: Distribution of two-day mean daily maximum and minimum temperatures for English regions

Region	Threshold temperature (ºC)		
	93rd (maximum)	95th (maximum)	10th (minimum)
South West (SW)	22.3	23.0	1.1
South East (SE)	23.5	24.5	0.3
London (LN)	24.7	25.9	1.6
East of England (EE)	23.9	24.9	0.1
West Midlands (WM)	23.0	24.0	-0.1
East Midlands (EM)	23.0	24.0	-0.1
North West (NW)	21.6	22.7	0.5
Yorkshire and Humberside (YH)	22.2	23.2	0.3
North East (NE)	20.9	21.8	0.4

[4] Population weighted temperatures have been used in this assessment to reflect the impact on human health as opposed to any other factor. As a result, temperatures better reflect where people live rather than average temperatures over a large region where few people may live. The same methodology has also been applied for the same reasons for Indicator 30, Trends in very wet days (Section 3.10).

Results

Figure 3.1 and Figure 3.2 show the number of days the population weighted maximum temperature exceeds the 93rd and 95th percentile of the two-day average maximum temperature for each region. For both thresholds, there is a strong correlation between the number of days each threshold is exceeded. For all regions, there is a large variability in the number of hot days per year, although there is an underlying trend over the assessment period for the number of days exceeding the threshold to increase by 1 day every 3 years for the 93rd percentile and 1 day every 4 years for the 95th percentile. The south-west typically has 1-2 days more hot days than other regions, suggesting a greater range of temperatures specific to this region.

Across regions, the correlation between the number of hot days is weaker, although still relatively high, with regions that are geographically near to each other being more closely correlated than those that are further apart. For example, the weakest correlated regions are the north-west and the south-east, and the strongest correlation regions are London and the south-east. Figure 3.3 shows the number of days the maximum temperature exceeds the two-day average 93rd percentile for England based on the same population weighted average used for the regions. Also shown is the 5-year running average[5]. This highlights the trend in the number of hot days per year discussed for the regions above, as well as a number of years where there were a large number of hot days in a year, most notably 1976, 1983, 1989, 1995, 2003 and 2006.

> The average number of days above the different heat thresholds are typically less than would be anticipated statistically. For the average number of days below the cold threshold, the reverse is true. This mainly reflects the time period of 1993-2006 to determine the thresholds which was warmer on average than the time period analysed, i.e. 1960-2011. However, it also reflects the different data sets used in the analysis, as well as the different methods used to determine the population weighted temperatures and the use of the two-day average used to determine maximum and minimum temperatures. This is not considered significant as the general pattern of temperatures above (or below) a high threshold and any possible trends in these temperatures are what is significant for this report.

[5] This is the average of the current year and the two years both before and after this year.

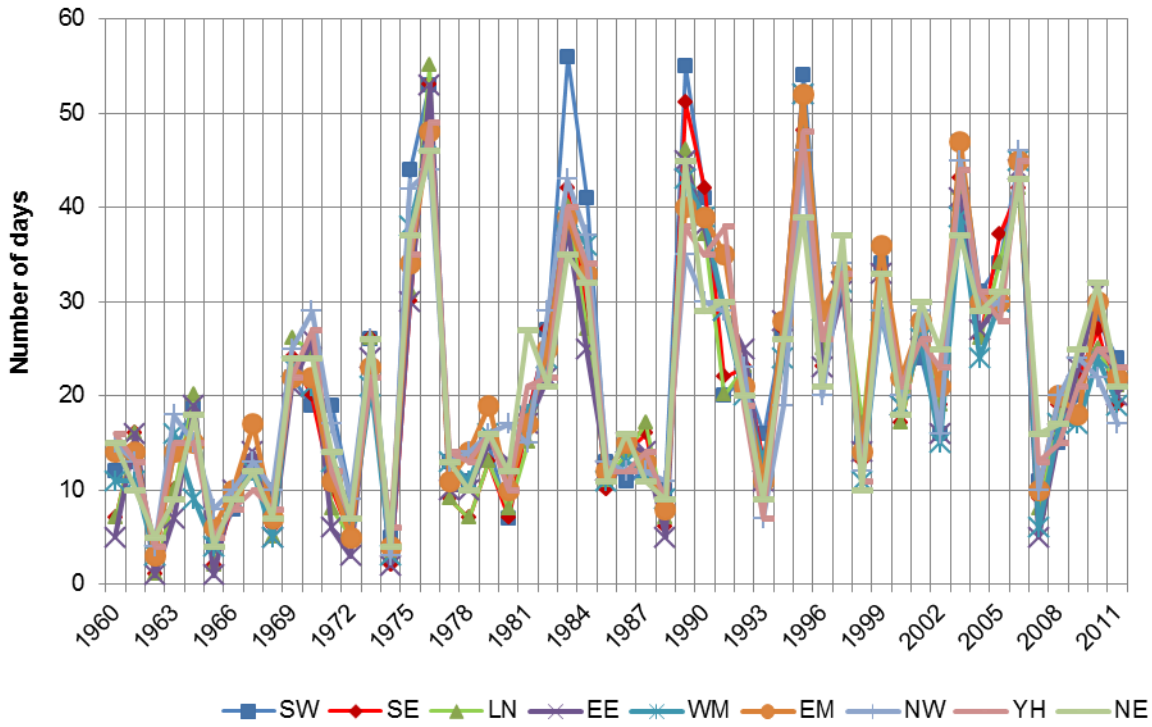

Figure 3.1: Number of days per year the daily maximum temperature exceeds the 93rd percentile of the two-day average maximum temperature for each English region

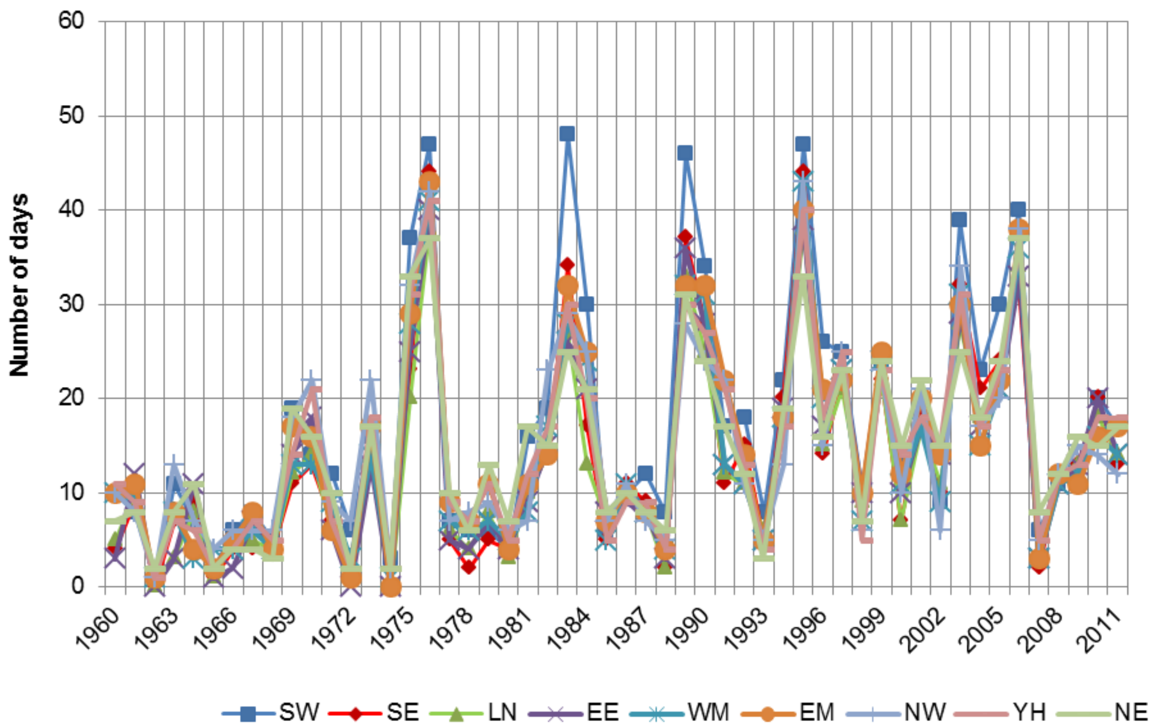

Figure 3.2: Number of days per year the daily maximum temperature exceeds the 95th percentile of the two-day average maximum temperature for each English region

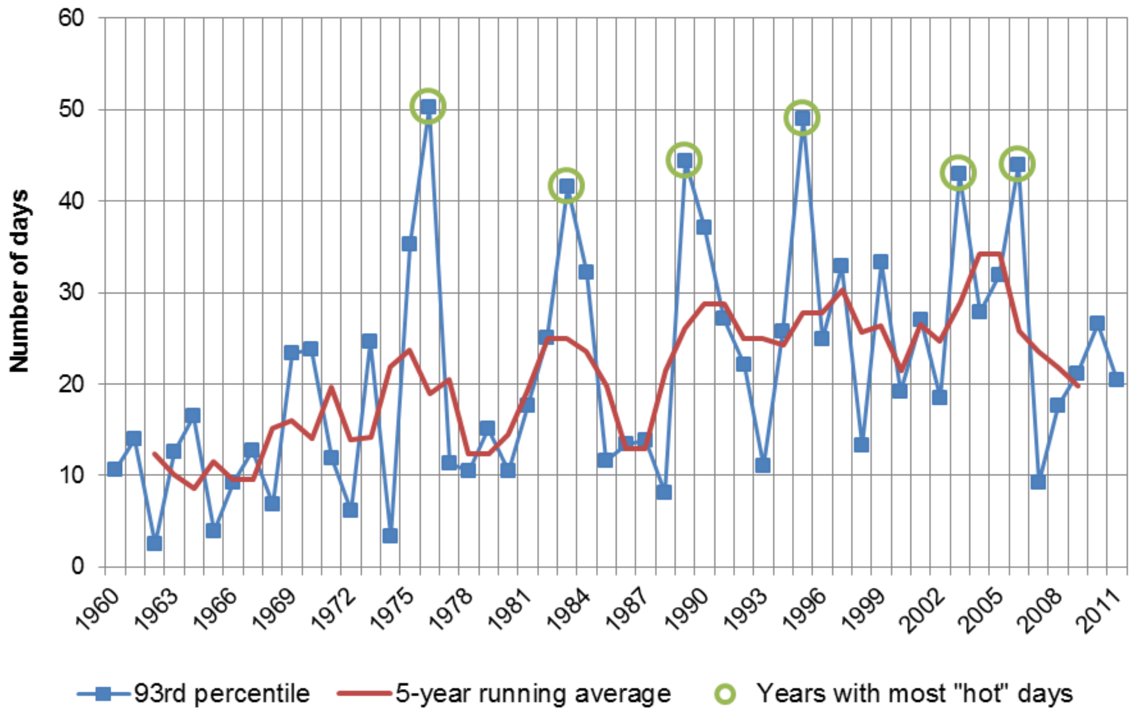

Figure 3.3: Trends in the number of days per year the daily maximum temperature exceeds the 93rd percentile of the two-day average maximum temperature for England

Figure 3.4 shows the number of days the population-weighted minimum temperature is below the 10th percentile of the two-day average minimum temperature for each region. This highlights several years where there are significantly more days than average below the 10th threshold for minimum temperatures, most notably 1963, 1969, 1979 and 2010. In addition, several years are noted when there are fewer days below the 10th threshold than average for minimum temperatures, which are 1974, 1990, 2002 and 2011. There is also a noticeable trend in a reduction in the number of days where the minimum temperatures are below the 10th threshold. This is indicated on Figure 3.5, which shows a 5-yearly running average for England. This suggests that over the period 1960-2011, the number of days below this threshold has reduced by approximately 15-20 days. This is a similar level to the increase in the number of hot days over the same time period as noted above. Strong correlation is also noted across the regions, with a similar number of cold days per year for each region, although based on a different minimum temperature, and a similar trend as noted for England as a whole.

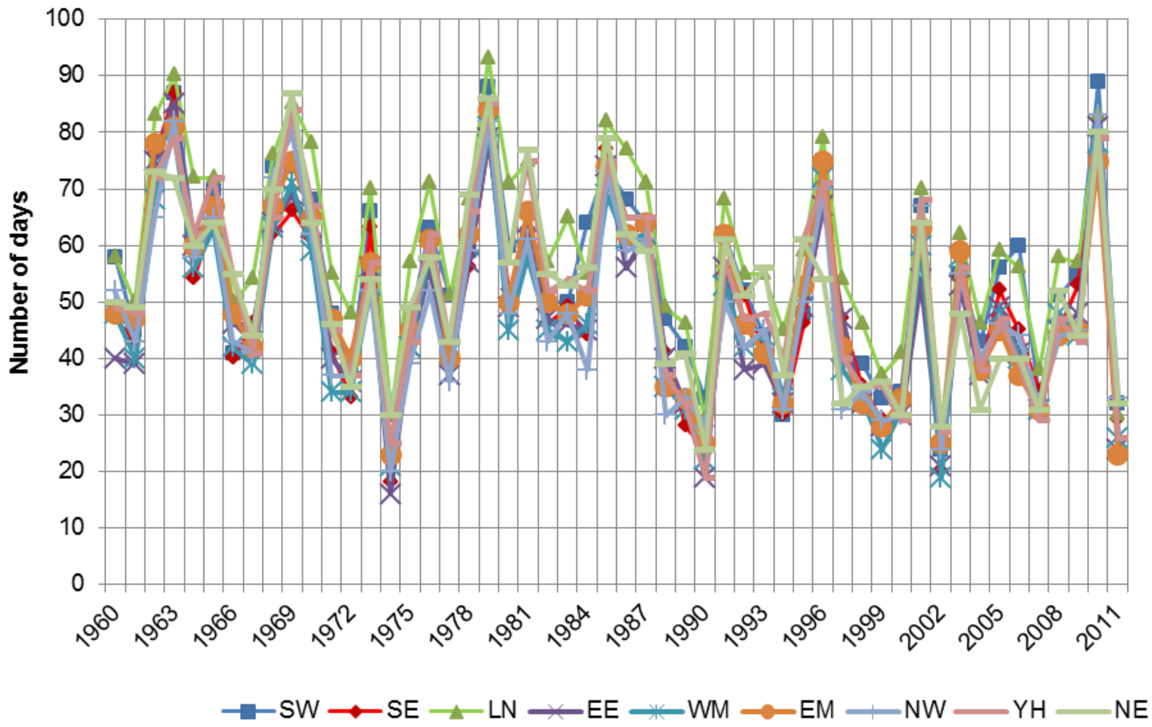

Figure 3.4: Number of days per year the daily minimum temperature is below the 10th percentile of the two-day average minimum temperature for each English region

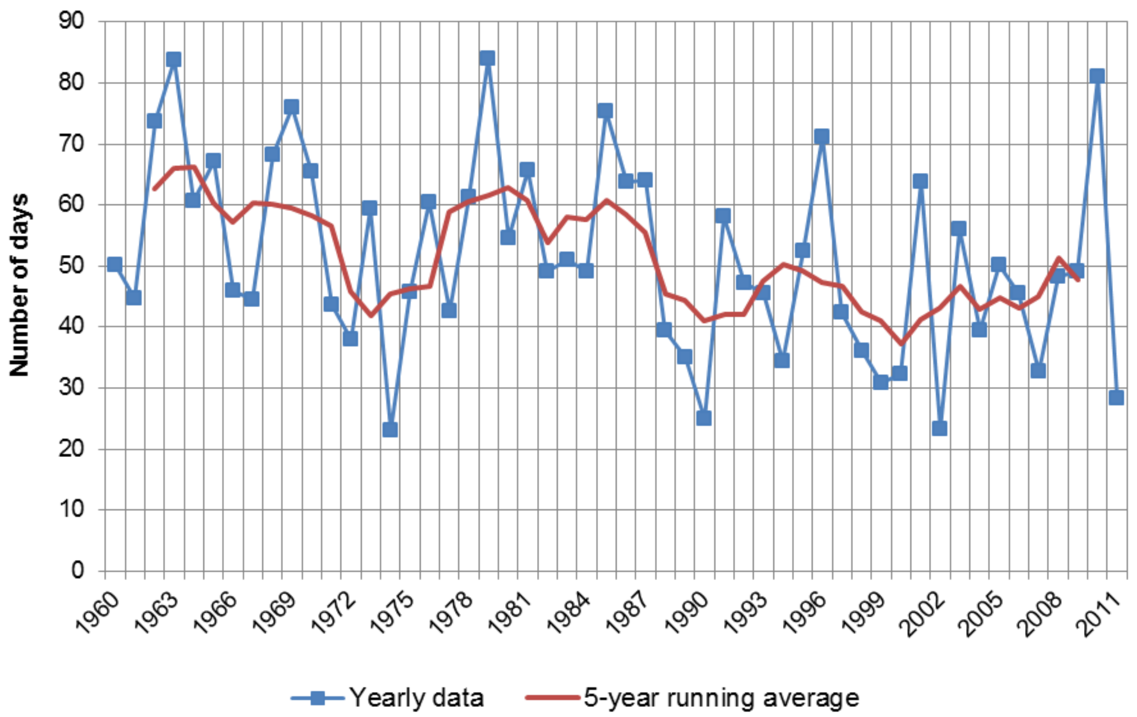

Figure 3.5: Trends in the number of days per year the daily minimum temperature is below the 10th percentile of the two-day average minimum temperature for England

3.2. Indicator 3: Trends in urban and rural temperatures

Introduction

The Urban Heat Island (UHI) describes the phenomenon that, in general, temperatures in urban areas are higher than those in surrounding rural or suburban areas. There are a number of reasons for this, including the physical properties of urban building materials like concrete, and the lack of moisture and vegetation in urban areas. Many urban building materials absorb heat throughout the day and release it slowly at night, meaning that the UHI is often more pronounced during the night. The UHI is also enhanced when wind speeds are low and there are no clouds, such as during heatwave periods. Due to the computational necessity of using low spatial resolution in many climate models, the smaller scale effects of urban surfaces are usually not explicitly included in climate projections such as the UK Climate Projections (UKCP09). Since a large proportion of the UK population live in cities, it is reasonable to suggest that they are at a greater risk from overheating during summer. It is possible that during winter months, the UHI gives a protective effect on the same population when temperatures in cities do not drop as low as in surrounding rural areas. Apart from location, an important factor determining the temperature related health impacts is housing design, heating, ventilation, cooling, insulation, thermal mass, shading and internal heat gains.

It is difficult to measure past trends in the UHI, due to a lack of observations in urban centres, because historically, monitoring stations were mainly sited away from city centres. It has been suggested that temperature trends in urban and rural locations over the last few decades have been largely similar, so that although urban areas are generally warmer, the increase in temperature in urban areas is at the same rate as in surrounding rural locations (Jones *et al.* 2009; Jones and Lister 2009). For this indicator we present trends in maximum and minimum urban temperature for 5 urban locations in the UK, as well as 5 nearby rural locations from 1961 to 2010. We also include a similar series for central London. This gives an idea of the absolute temperature in a range of cities in England, geographically spread out. In order to estimate the intensity of the UHI, we calculated the difference between urban and rural minimum temperatures for each of the 5 locations, and investigated the trend in UHI intensity over the period from 1960-2011. The UHI intensity for London was not calculated due to the lack of rural type grid cells in the vicinity of the city. Wilby *et al.* (2011) looked at trends in the London UHI from the late 1950s, and found no clear long-term trend: instead UHI intensity showed slight positive and negative trends on decadal time scales, as a result of weather patterns and anthropogenic activity.

Methodology

As for Indicator number 1 (Section 3.1), the Met Office 5 km x 5 km gridded dataset for the UK was used, but without population weighting. Instead 5 km grid cells were selected centred on 5 English cities: Birmingham, Bristol, Manchester, Nottingham and Newcastle as well as grid cells located close by each city to represent rural areas. The rural cells were chosen by selecting the grid cell closest to each city centre which contained little or no urbanisation, based on the land surface scheme provided by the Met Office and used in producing the gridded datasets. The 5 cities were chosen to represent a range of large cities which span much of England, and for which grid cells coincided with the very centre of the city. A central London grid cell was also included, although there is no corresponding rural cell since the nearest rural cells were positioned a large distance from London and therefore did not represent a good comparator. London urban temperatures were included since they are representative of the largest UK city, and can be compared with the other city centre temperatures.

The Met Office gridded dataset includes an urban land surface scheme which means that urban temperatures are well represented by the dataset. By selecting grid cells in the very centre of each city, the

risk is minimised that any observed changes in temperature are related to changes in urbanisation, based on the assumption that in the very centre of the city, the extent of urbanisation will not have changed significantly since the 1960s, although of course the nature of the building type may have changed. The volume of traffic and other sources of anthropogenic heat emissions are also likely to have increased since the 1960s.

Results

1. Maximum and minimum temperature time series for urban and rural locations from 1960-2011

Annual means of daily maximum and daily minimum temperatures for urban and adjacent rural locations for the 5 cities were analysed, and linear trends were calculated. Annual urban trends for maximum and minimum temperature for London were also calculated. Figure 3.6 and Figure 3.7 show annual mean daily maximum and minimum temperatures from 1960 to 2011 for each urban location: 6 cities including London. Figure 3.8 and Figure 3.9 show the same for adjacent rural locations, and exclude London.

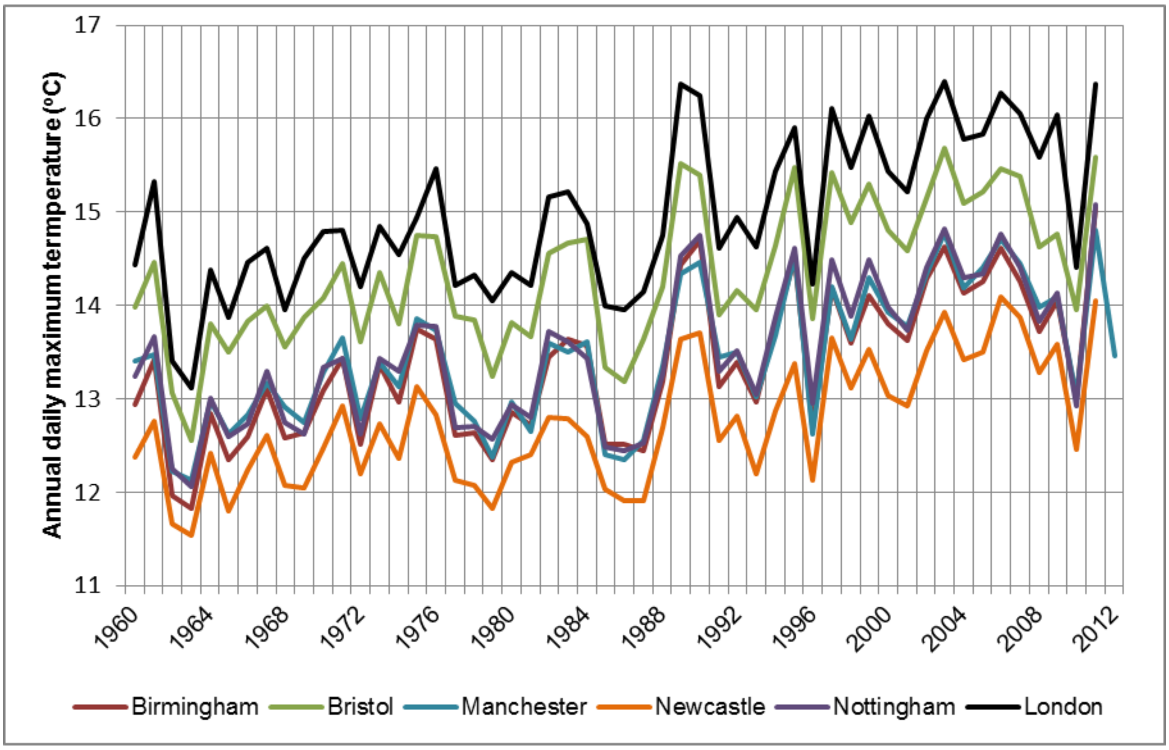

Figure 3.6: Annual mean daily maximum temperatures for six urban locations in England over the period 1960 to 2011

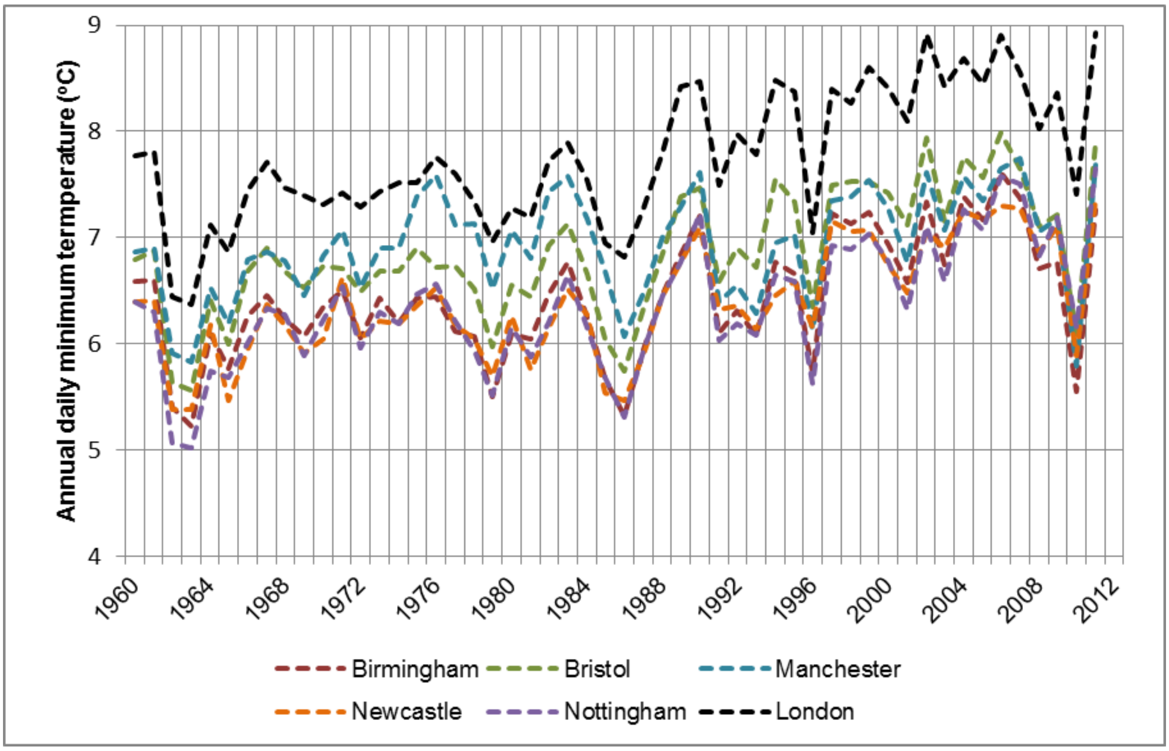

Figure 3.7: Annual mean daily minimum temperatures for six urban locations in England over the period 1960 to 2011

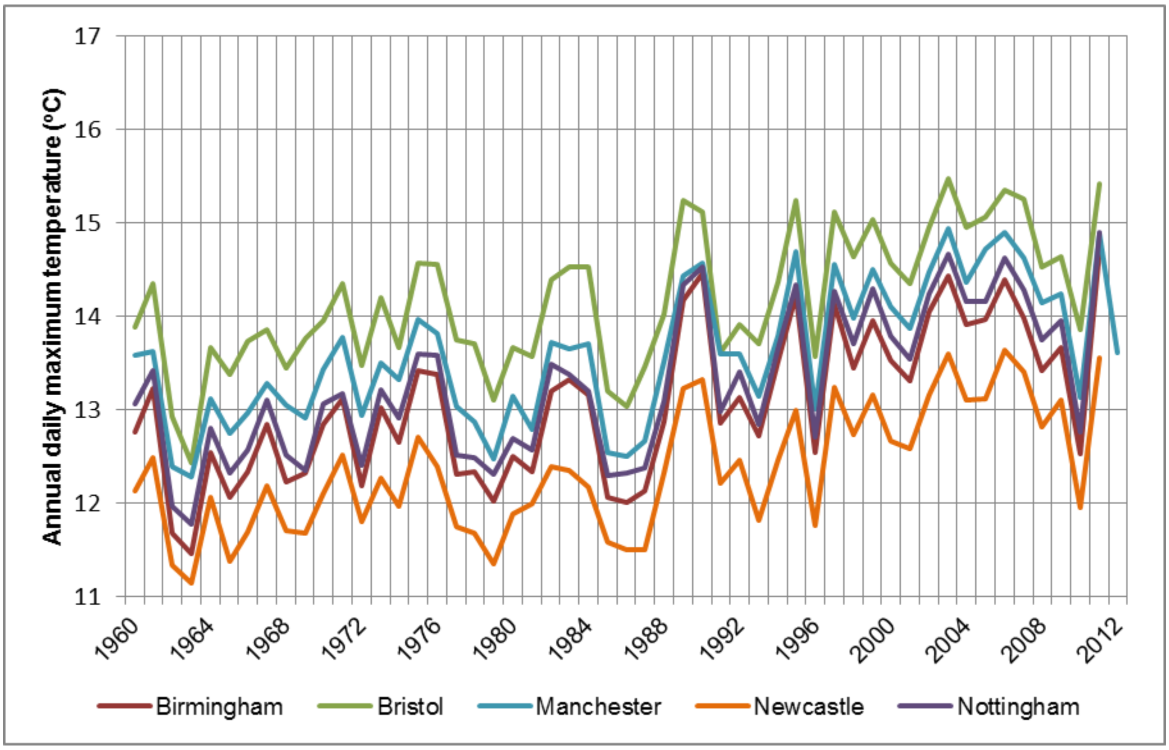

Figure 3.8: Annual mean daily maximum temperatures for 5 rural locations in England, adjacent to highlighted cities over the period 1960 to 2011

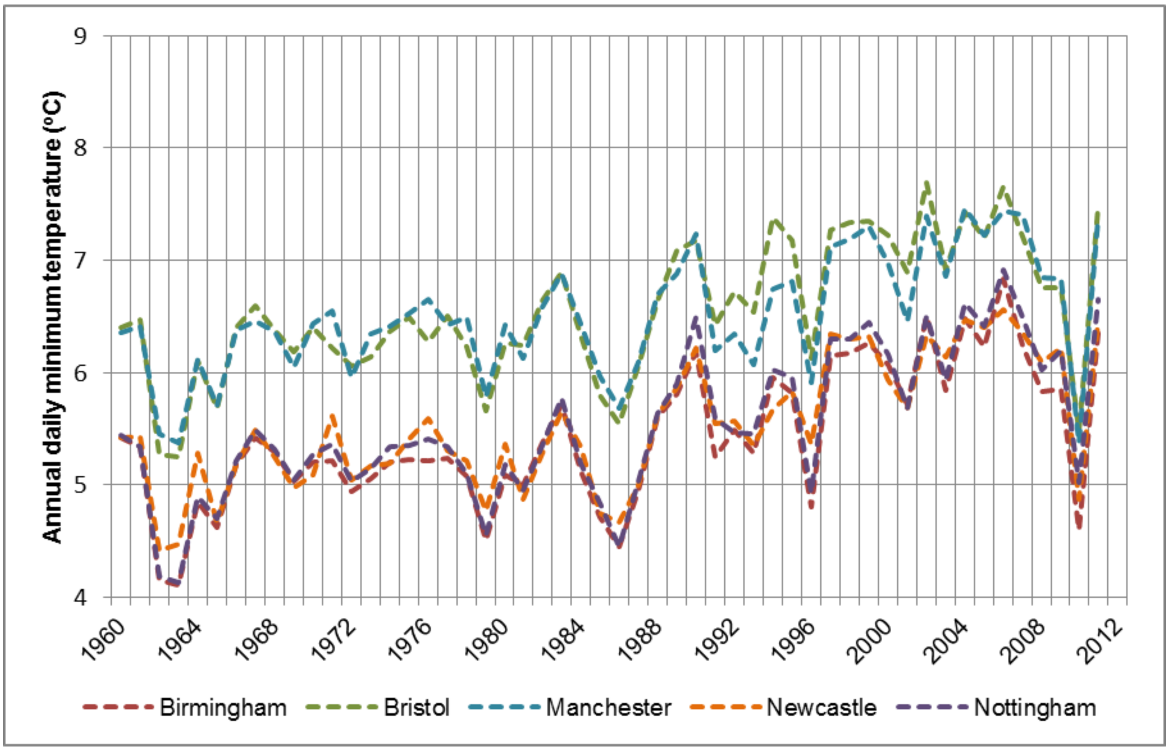

Figure 3.9: Annual mean daily minimum temperatures for 5 rural locations in England, adjacent to highlighted cities over the period 1960 to 2011

The temperature difference between urban and rural locations is small compared with the difference between maximum and minimum temperatures, and urban temperatures are generally greater than rural (Figure 3.6 and Figure 3.8). The difference between maximum temperature in urban and rural areas is generally smaller than the difference between urban and rural minimum temperatures. This reflects the fact that the UHI is usually more intense at night time, so there is an enhanced minimum temperature at night time in urban areas. Peak daytime (maximum) temperatures do not vary as much between urban and rural locations. Overall, there is strong correlation in temperature between locations.

2. Trends in maximum and minimum temperatures from 1960 to 2011

All the time series presented in Figure 3.6-3.9 show positive trends over the period, reflecting the general increase in maximum and minimum temperatures over the last few decades in England (see indicator 3.1, Section 3.1). Figure 3.10 summarises the trends in each of the time series. Figure 3.10a represents trends in annual mean daily maximum temperature and Figure 3.10b represents trends in annual mean daily minimum temperature. All bars are positive, since all the time series show an increase in temperatures over time. The height of the bars shows the size of the trend in temperature, or how positive the trend is. London maximum temperatures have the strongest positive trend: an increase of 0.37^{o}C per decade (Figure 3.10a). Trends in daily maximum temperatures (Figure 3.10a) are more positive than trends in daily minimum temperature (Figure 3.10b), i.e. daily maximum temperatures are rising more quickly than daily minimum temperatures in this dataset.

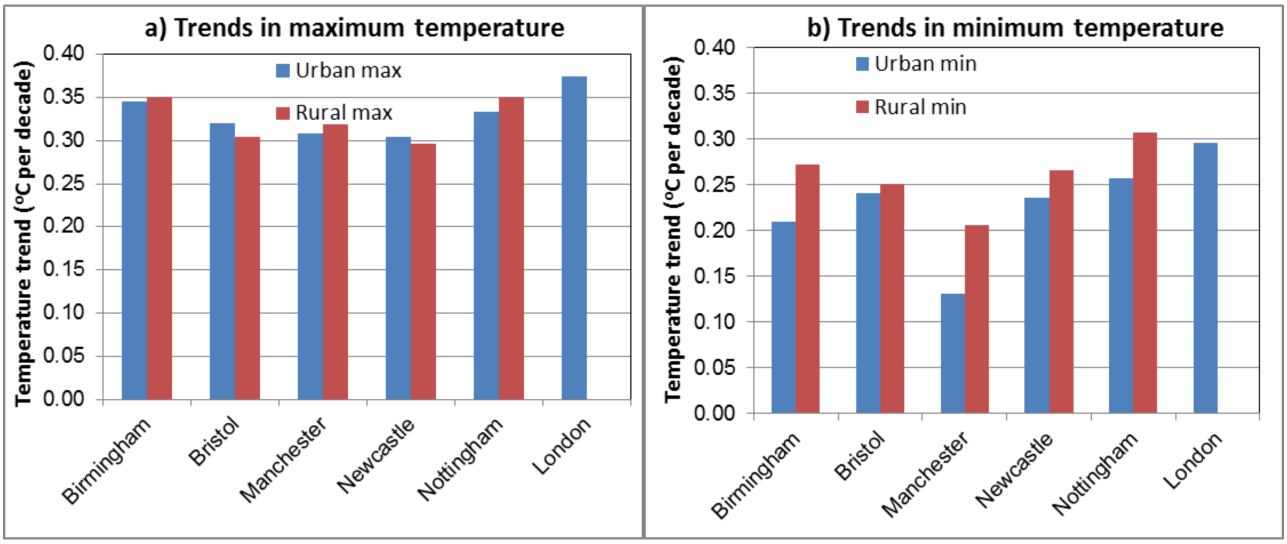

Figure 3.10: The decadal trend in a) maximum and b) minimum temperature (increase in ºC per decade) for each location, sorted by urban or rural type (1960 to 2011)

Although daily maximum temperature trends are increasing more rapidly than daily minimum temperatures, there is no clear difference between urban and rural maximum temperature trends (Figure 3.10a). For Birmingham, Manchester and Nottingham, rural maximum temperatures are rising slightly faster than urban maximum temperatures, and the opposite is true for Bristol and Newcastle. This suggests that although maximum temperatures are rising in all locations, there is no clear difference between maximum temperature trends in urban or rural areas. As noted earlier, maximum temperatures do not differ as much as minimum temperatures between urban and rural locations.

Trends in annual mean daily minimum temperatures are smaller than for daily maximum temperatures, although they are still positive for all locations (Figure 3.10b). In contrast with the maximum temperatures, there is a suggestion of an urban-rural contrast in minimum temperatures trends, with all 5 geographic locations showing a faster increase in rural minimum temperatures than for urban minimum. As discussed above, the UHI tends to be more intense at night and is therefore more likely to influence daily minimum temperatures. Figure 3.10 indicates that rural minimum temperatures have become closer to urban minimum temperatures over the last 5 decades.

3. An estimation of the trend in UHI intensity

The UHI intensity can be described as the difference in temperature between urban and rural locations (Oke 1982). In order to investigate any variations in UHI intensity, we calculated the difference between annual urban minimum temperatures and the corresponding adjacent rural temperatures for the five cities (Figure 3.11). Minimum temperatures were chosen since these reflect the characteristics of the UHI better than maximum temperatures, and there was a greater difference between urban and rural minimum temperatures. Trends in the difference between urban maximum and rural maximum were small and inconsistent between locations in terms of sign (not shown).

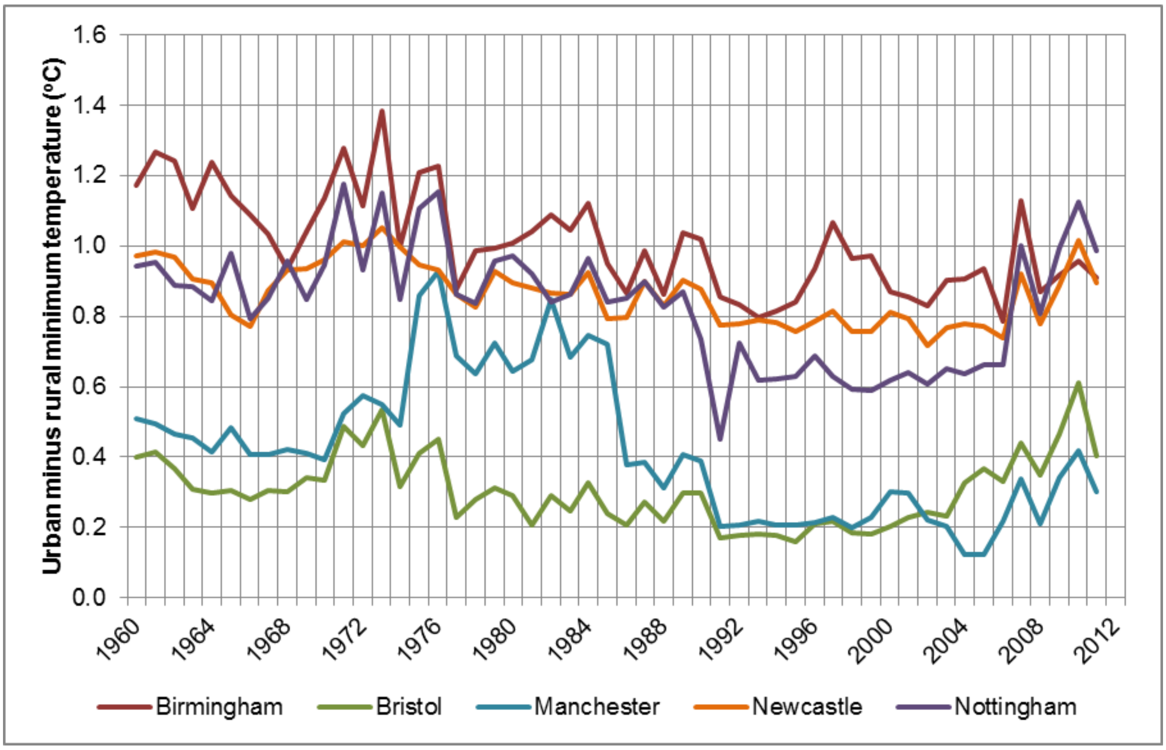

Figure 3.11: The difference between urban and rural annual mean daily minimum temperature for each city and corresponding adjacent rural location over the period 1960 to 2011

In general, Figure 3.11 suggests a decrease in UHI intensity over the period 1960-2011, characterised by a negative trend in the difference between urban and rural minimum temperatures (particularly for Birmingham, Newcastle and Nottingham), although there is some variability in the temperature difference, particularly for Manchester, which shows a peak in the late 1970s for around a decade, and no clear trend for Bristol. It is important to note that even though the UHI intensity may be decreasing, absolute temperatures in both urban and rural areas are increasing over all.

4. Summary

The results for this indicator show that daily maximum and daily minimum temperatures have risen in both urban and rural areas in the locations chosen for England since 1960 (Figures 3.6 and 3.7). Maximum temperatures are rising faster than minimum temperatures are rising (Figure 3.8). In terms of urban and rural differences, there is no clear distinction between the rate of increase of maximum temperature between urban and rural locations. In contrast, for minimum temperatures, the rate of increase is higher in rural areas than in urban areas. This suggests that rural night time temperatures have been increasing to become closer to urban night time temperatures over the last 5 decades.

An estimate of a trend in UHI intensity, calculated by subtracting rural minimum temperatures from urban minimum temperatures and analysing the trend for each location, showed that for the cities studied, there is a negative trend in UHI intensity over the period 1960-2011 (Figure 3.9). However, even though there is a slight reduction in UHI intensity (the temperature difference between urban and rural) in these locations, both urban and rural temperatures have risen throughout the period. The reduction in UHI intensity in the cities studied is largely due to increasing rural night time temperatures rather than a fall in urban night time temperatures.

This is just one estimate of the trend in UHI intensity, and caution should be applied when interpreting the results. The data used was based on average temperatures for particular grid cells, rather than monitoring station point measurements, since this data was not freely available for the analysis. Although we can investigate trends in urban and rural temperatures, we cannot attribute any changes in UHI intensity to a particular cause. The cities used give a representative example of English cities, although the results cannot be extrapolated to other English cities without further analysis. Although it is unlikely that the amount of urbanisation in the very centre of each city has changed significantly over the period, traffic, air pollution, anthropogenic heating and the nature and form of the buildings and layout are likely to have changed, which will have an effect on local temperatures. In addition, since we are studying the difference between urban and rural minimum temperatures, any variations in UHI intensity could be due to changes in either urban or rural locations, such as modifications to land use. Therefore trends in UHI which are representative of any one particular city cannot be applied to other cities.

3.3. Indicator 4: Number of heatwave alerts

Under the Heatwave Plan, a Heat-Health Watch alert system operates from 1st June to 15th September each year. During this period, the Met. Office may forecast heatwaves based on forecasts of day and night-time temperatures and their duration. Five levels of heatwave alerts are issued, and these are outlined in Table 3.2.

Table 3.2: Heatwave alert levels

Level	Alert
0	Long-term planning All year
1	Heatwave and Summer preparedness programme 1 June – 15 September
2	Heatwave is forecast – Alert and readiness 60% risk of heatwave in the next 2–3 days
3	Heatwave Action Temperature reached in one or more Met Office National Severe Weather Warning Service Regions
4	Major incident – Emergency response Central Government will declare a Level 4 alert in the event of severe or prolonged heatwave affecting sectors other than health

Level 0 is year round long term planning, so that longer term actions (such as those linked to spatial planning and housing) are taken to reduce the harm to health of severe heat when it occurs. Level 1 encourages organisations to plan for the summer while Levels 2-3 are based on threshold day and night-time temperatures both exceeded in an individual day as defined by the Met Office. These vary from region to region, and the threshold temperatures for each region are given in Table 3.3 below. Level 4 is a judgement at national level made as a result of a cross-Government assessment of the weather conditions, and occurs when the impacts of heat extend beyond the health sector.

Table 3.3: Threshold temperatures (ºC) for National Severe Weather Warning Service regions

Region	Day	Night
South West (SW)	30	15
South East (SE)	31	16
London (LN)	32	18
East of England (EE)	30	15
West Midlands (WM)	30	15
East Midlands (EM)	30	15
North West (NW)	30	15
Yorkshire and Humberside (YH)	29	15
North East (NE)	28	15

Although heatwave alerts are published by the Met. Office, no readily accessible archive of past heatwaves alerts currently exists. Information on heatwave alerts issued for the current year (2013) is held at PHE (shown in Table 3.4), although they do not hold archives for past years.

Table 3.4: Heatwave alerts issued in England in 2013

Date	SW	SE	LN	EE	WM	EM	NW	YH	NE
11/07/2013	60	60	60	60	50	60	30	70	30
12/07/2013	70	60	60	60	50	70	30	90	30
13/07/2013	90	60	60	60	50	60	30	60	30
15/07/2013	40	60	60	60	40	60	30	40	30
17/07/2013	60	90	90	80	60	60	30	60	30
18/07/2013	90	90	90	80	90	80	30	60	30
19/07/2013	90	60	60	40	90	60	90	60	30
20/07/2013	60	60	60	60	60	60	60	60	30
22/07/2013	70	90	90	90	70	70	70	60	20
23/07/2013	40	90	90	90	40	60	20	40	20
24/07/2013									
30/07/2013	30	60	50	60	30	50	20	30	20
01/08/2013	30	60	50	60	30	50	20	30	20
01/08/2013	30	60	60	60	30	50	20	30	20
02/08/2013									

Note: Numbers given are the probability of a heatwave in the next 2-3 days.

It is therefore not possible to currently indicate any trends in heatwave alerts, although a few conclusions can be drawn on the heatwave alerts issued in 2013. These are:

- All heatwave alerts occurred over a three week period from 11th July to 2nd August.
- Heatwave alert levels generally increased the further south you went, despite the generally higher threshold temperatures in this region.
- No heatwave alerts greater than Level 1 were issued for the north-east in 2013. This was despite it having the lowest daytime threshold temperature.

3.4. Indicator 5: Amount of urban greenspace and bluespace

Introduction

Greenspace and bluespace such as parks, open spaces, rivers and water bodies, have a dual function in combating the Urban Heat Island effect. Firstly their inherent cooling, and for green infrastructure, shading capacity reduces the heat vulnerability of the surrounding area. Secondly, they provide valuable climate refuges, to which local residents can go for temporary respite from extreme heat (Capon and Oakley, 2012). There is also an important association between access to green spaces and better mental and physical health (Alcock *et al.*, 2014).

Green infrastructure can take many forms from large open spaces such as parks to smaller scale features such as domestic gardens and street trees. In recent hot summers, drying out of green space has been

observed, for example the parched grassland in Hyde Park in 2006. Under prolonged hot, dry conditions, evapo-transpiration of the green space slows down, eventually shutting down if the vegetation becomes completely parched. Consequently, the cooling effect of the green space is effectively switched off. Without planned adaptation, this could become an ever more frequent occurrence as summers become hotter and drier. This has clear consequences for the Urban Heat Island and overheating, and subsequent human health effects (Amson, 2012).

Methodology

To assess this indicator the Ordnance Survey (OS) MasterMap Topography Layer was used as it gives complete coverage of England. Each polygon within the dataset is classified into:

- Manmade
- Natural
- Multiple.

Urban greenspace was defined as the 'natural' polygons within the urban mask and the permeable component of the 'multiple' polygons. Devising the permeable part of the multiple polygons was based upon recent research on urban creep (HR Wallingford, 2012). This gave us the area of impermeable surface from which we were able to derive the permeable surface to include in the greenspace total. Permeable surfaces in the multiple land use category generally do not include permeable paving; rather they are made up of domestic gardens that are not paved. Domestic permeable paving will be included in the impermeable component of the Multiple category and non-domestic included in the Manmade category, but it is not possible to estimate how much of these components it makes up (HR Wallingford 2012).

Bluespace is a subset of the natural part of the MasterMap Topography layer and is calculated as where there is a water body. Water bodies include streams, rivers, lakes and canals.

A mask was created to identify the urban areas. This was derived from the property density of 1km cells. Initially, only 1km cells with a property count of over 500 were considered to be urban. This meant that cells that had a large amount of greenspace in the centre of cities were not taken into consideration.

As a result we took into account the values of the neighbouring cells and calculated an average of the central cell and the surrounding eight cells. This smoothed the values giving a better definition of urban edges and provided a more complete coverage in the centre. Again a threshold of 500 was used to identify urban cells.

The smoothing meant that some small settlements were not picked up as the cells surrounding them had very low property counts. Therefore the original urban cells were also included to provide a total urban mask.

Results

The results are presented for snapshots in time in Table 3.5, with results by Local Authority for 2013 in Figure 3.12 and Figure 3.13. This indicates a significant reduction in urban greenspace over the period 2001 to 2008 of about 70,000 hectares, approximately equal to the area of Merseyside. 24,000 hectares of this is principally a result of greenfield development, urban infill and property extensions with the remaining greenspace loss being through paving of gardens with driveways, hardstandings and patios. The latter accounting for 14% of the multiple land surface becoming impermeable during this period. Since 2008, the rate of reduction in urban greenspace has reduced significantly, although still showing a linear trend of approximately 1,000 hectares per year.

As for urban bluespace, this has remained relatively constant since 2001. Although the analysis shows an increase of about 200 hectares since 2001, this is not significant.

It should be noted that the base classification of early versions of MasterMap differs from that of later versions and improvements in accuracy have been made. This may have an impact on the results reported here, although the classifications are quite broad and less likely to be affected by minor changes between classes and the later years (from 2008 onwards) can be considered as being more consistent.

Table 3.5: Amount of urban greenspace and bluespace in urban areas across England (thousands of hectares)

Land type	Year			
	2001	2008	2011	2013
Greenspace	1028	959	956	954
Bluespace	20.0	20.1	20.2	20.2

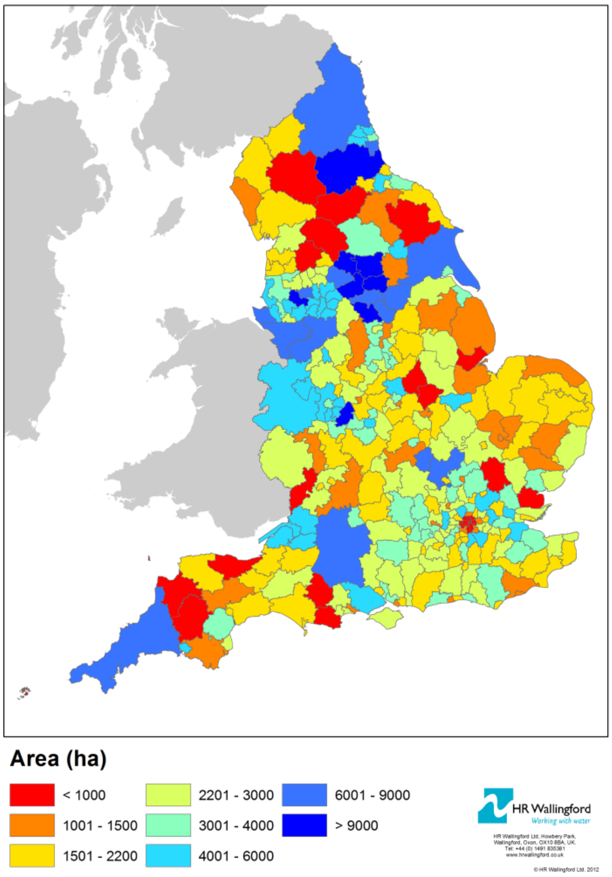

Figure 3.12: Urban greenspace for 2013 by local authority

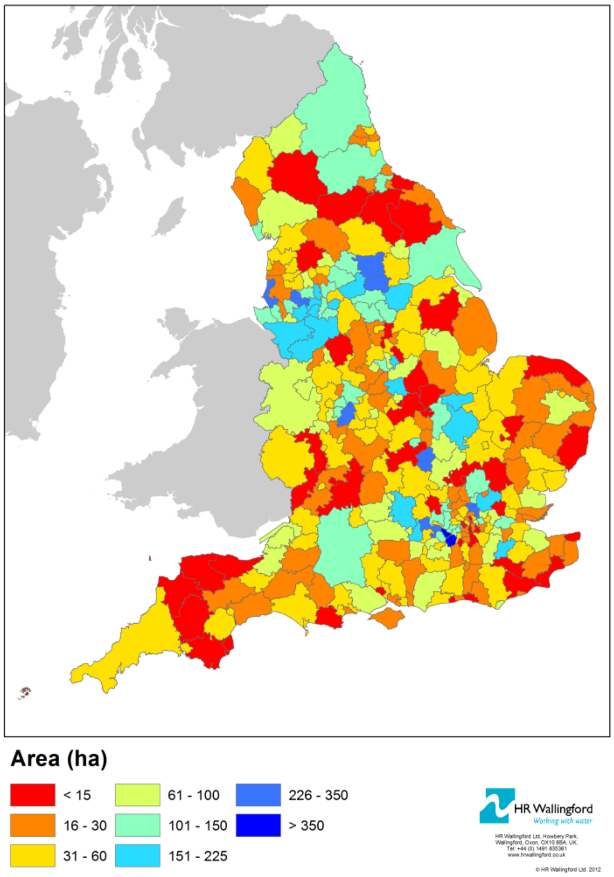

Figure 3.13: Urban bluespace for 2013 by local authority

3.5. Indicator 7: Vulnerable people in urban areas

Introduction

Urban populations are vulnerable to a range of environmental exposures, such as increased risk of mortality from heatwaves, elevated levels of air pollution, noise pollution and contamination of water and soil. Cities tend to be densely populated, with populations representing a wide range of socio-economic classes, including the most poor, the elderly, the very young, and those with pre-existing illnesses representing some of the most vulnerable groups.

For this study, two sub-groups of vulnerable people have been considered. These are the elderly, defined as those over 75, and the very young, defined as those under 5. These two groups are in particular vulnerable to heat.

Results

The 2011 census was used to determine the number of people over the age of 75, and under the age of 5 living in urban areas. This was based on the age distribution of the population which is covered by indicator 13, Section 3.8, with the results shown in Figure 3.9.

Table 3.6 shows the breakdown of this figure for those under 5 and over 75 living in urban locations. Figures for both rural locations and totals are given for comparison. This shows approximately 464,000 people under the age of 5 and 883,000 people over the age of 75 living in urban locations, respectively 5.0% and 9.5% of the population in urban areas. This is about 1.5% less for those under 5 and about 2% more for those over 75 when compared to those living in rural locations.

Table 3.6: Numbers under 5 and over 75 in urban and rural locations in England, and as a percentage of the total population in that area given in brackets (2011 census)

Age range	Number (urban)	Number (rural)	Number (total)
0-4	464,000 (5.0%)	2,854,000 (6.5%)	3,318,000 (6.3%)
75+	883,000 (9.5%)	3,225,000 (7.4%)	4,108,000 (7.7%)

The percentage of the population under 5 and over 75 in urban areas by Local Authority are shown in Figure 3.14. Also shown for comparison in Figure 3.15, is the percentage of the population in urban areas by Local Authority. The percentage bands for these figures have been chosen to approximately give equal numbers of Local Authorities in each band, so that a direct comparison between graphs can be easily made.

For children under 5, Figure 3.14 indicates that these tend to live in inland locations, with Figure 3.15 highlighting that the largest concentrations of children are in the most heavily populated inland areas such as London, Manchester and the surrounding areas. There is also a greater proportion of children under 5 living in more southerly locations, apart from as noted above, Local Authorities located on the coast. For adults over 75, the reverse is generally true. Proportionally, more over 75s live in Local Authorities near the coast. There are many Local Authorities near the coastline where at least 9% of the population are over 75 years of age, which is more than 1% higher than the total England population of over 75's. For the most heavily populated areas, the reverse is true. Few heavily populated areas have a relatively high population over the age of 75, particularly in London and the surrounding areas.

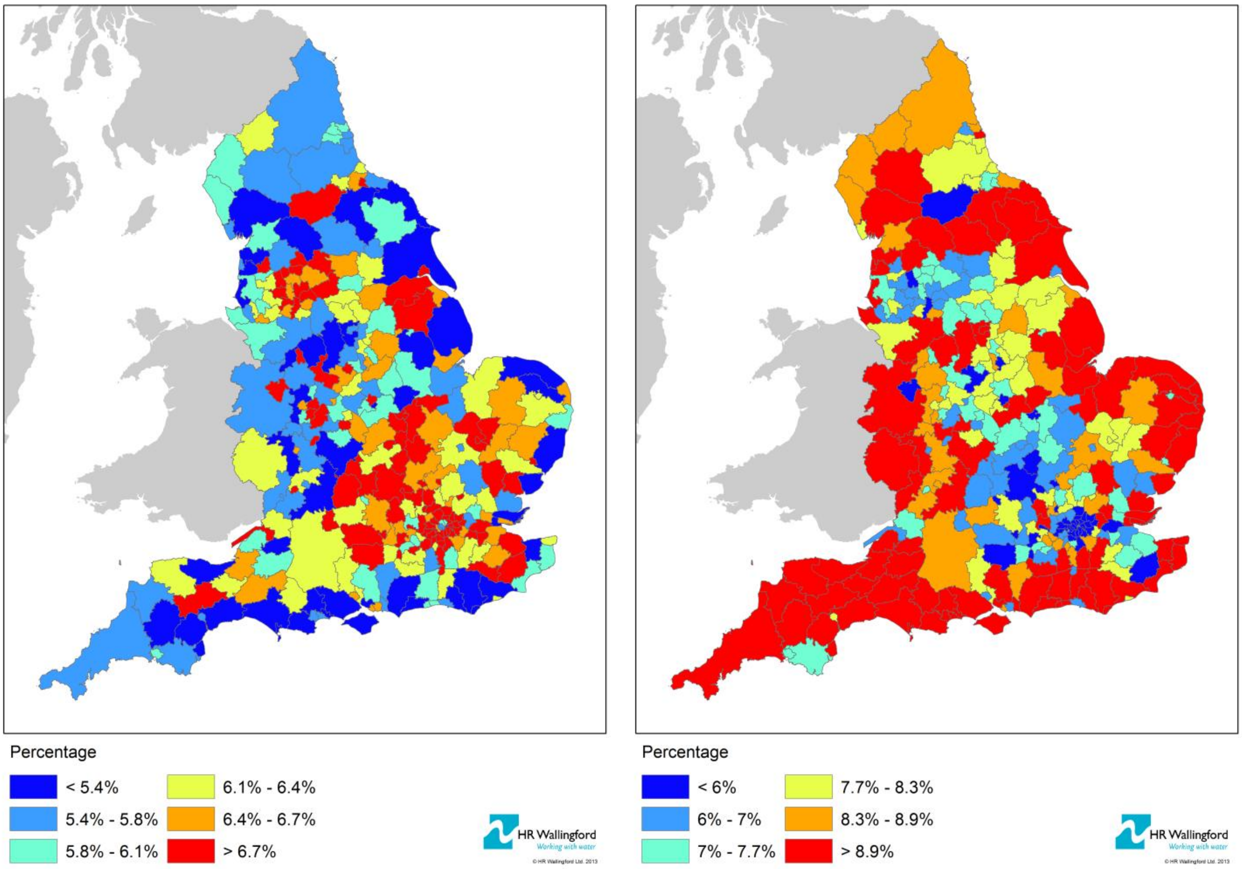

Figure 3.14: Percentage of population under 5 in urban areas (left) and over 75 in urban areas (right) by Local Authority

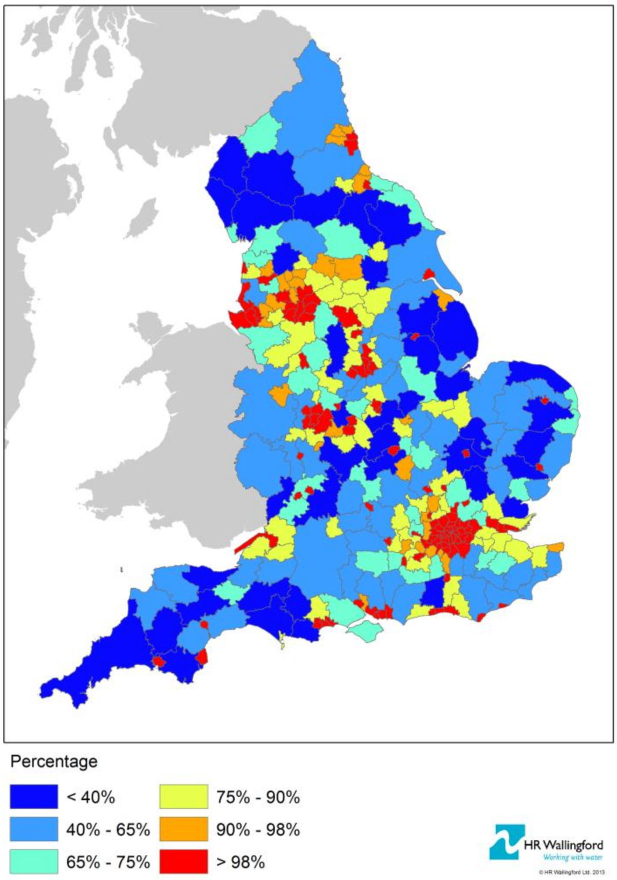

Figure 3.15: Percentage of population in urban areas by Local Authority

3.6. Indicator 8: Building types around the country

Introduction

The location, fabric, orientation and use of a building all contribute to the risk of overheating. Highly insulated buildings of lightweight construction, and those with glazed facades are particularly vulnerable to high temperatures, and many others are likely to become uncomfortable places to live and work in the future. These are likely to impact most on certain vulnerable groups, particularly those with pre-existing illnesses.

There are a number of factors that are likely to influence the overheating risk of properties, and these include:

- External climate - dwellings with low thermal mass are characterised by higher ‘climate change amplification coefficients’, or steeper slopes of the linear regression between internal and external temperature (Coley and Kershaw 2010);
- Location - summer temperatures are generally higher in the south, with built-up areas most at risk as a result of the urban heat island effect;
- Dwelling orientation and time of day– poor protection from solar gains, e.g. unshaded south and west-facing windows and east facing windows for rooms occupied in the morning;
- Room type – certain room types are more prone to overheating, such as bedrooms in newly built flats;

- Building fabric – internally insulated homes, especially those with a large occupation during the day, lightweight constructions and homes with dark facades, roof lights and large areas of unshaded glazing;
- Behaviour of occupants – occupants that are at home all day could be exposed to a greater overheating risk than those who do not;
- Building type and age – dwellings built around the 1960s and top floor flats are particularly at risk, as demonstrated for top floor flats by Vandentorren *et al.*, 2006 following the 2003 European heatwave. Newly constructed houses characterised by reduced heat losses, and hence increased thermal efficiency in winter, may not be suitably designed to cope with extreme summer temperatures;
- Ventilation – where noise and security issues discourage the use of window opening for cooling.

Methodology

To assess this indicator four types of residential properties were considered based on data available. The Environment Agency (EA) National Receptor Database 2011 was used to analyse these residential properties classified into:

- Flats;
- Terraced houses;
- Semi-detached houses;
- Detached houses.

This was undertaken on an urban and rural basis. Although it was not possible to assess these building types on specific factors such as outlined above, it was possible to assess the number of high rise flats, and this was considered as a subset (see Section 3.6.1).

Table 3.7: Number of different property types in English urban and rural areas based on the EA National Receptor Database 2011

Property Type	Flats	Terraced	Semi detached	Detached	Other
Urban	4,975,804	6,501,913	4,702,594	2,764,230	3,009,953
Rural	368,445	847,292	1,048,484	1,764,958	3,515,544
Total	5,344,249	7,349,205	5,751,078	4,529,188	6,525,497

From this table, few conclusions can currently be drawn. However, it is clear that there are significantly fewer flats and terraced properties in rural areas relative to detached properties.

3.6.1. High rise flats

As noted above, upper floor flats are a greater risk of overheating. Flats tend to be in urban areas (see Table 3.7), and being heated from the floors below, and with heat absorbed via the roof, all these factors result in a greater risk of overheating. Additional risk factors for flats are aspect, with single aspect flats being at greatest risk because there is limited potential for through flow of air to cool the flat. In addition, the type and insulation levels of the roof are also important determinants of overheating risk.

Aside from property type, the EA National Receptor Database also identifies an assigned floor level and building type. Flats were identified using the building type and the number of floors was calculated by taking the number of overlapping points and dividing the number of upper floors by the number of ground floors. High rise blocks were those that were identified as having more than four floors. High rise flats are individual

flats within the blocks. The rural/urban split of these flats was then derived by overlaying the urban mask (described in more detail in Section 3.4). The results of this assessment are shown in Table 3.8.

Table 3.8: Number of high rise flats in English urban areas

Flat type	Total	Urban	Rural	Proportion urban
High rise blocks	14,833	14,432	401	97%
High rise flats	236,669	225,932	10,737	95%
All flats	5,344,249	4,975,804	368,445	93%
% of all flats that are high rise flats	4.43%	4.54%	2.91%	

Results

As above, few conclusions can currently be made from this data. However, a clear majority of the high rise flats are in urban areas. These are the areas most likely to be affected by urban heating and are therefore at greater risk.

3.7. Indicator 9: Standard Assessment Procedure

3.7.1. Introduction

A number of studies have identified that an unintended consequence of high insulation and air tightness standards of newly built and retrofitted houses may be overheating (Zero Carbon Hub 2010), with the potential for them to be at higher risk of overheating than older, less well insulated houses (Young *et al.*, 2007 and Pathan *et al.*, 2008). Although the relationship between winter thermal efficiency and summer overheating is a complex interaction between a number of factors, including insulation, thermal mass and weather conditions, the Standard Assessment Procedure can be considered a potential proxy indicator of indoor risk of overheating.

3.7.2. Methodology

The Standard Assessment Procedure (SAP) is the methodology used by the Department of Energy and Climate Change (DECC) to assess and compare the energy and environmental performance of residential dwellings. Since 1995, when it was first published, it has been a legal requirement for all new properties to have a SAP rating. The SAP is reviewed on a regular basis, the last of which took place in October 2013.

SAP works by assessing how much energy a dwelling will consume, and how much carbon dioxide (CO_2) will be emitted in delivering a defined level of comfort and service provision based on standardised occupancy conditions. It was developed by the Building Research Establishment (BRE) for the former Department of the Environment in 1992, and is based on a model developed by the Building Research Establishment to estimate the energy consumption of different dwelling types regardless of geographical location and aspect.

The SAP rating is adjusted for floor area so that it is essentially independent of dwelling size for a given built form, and expressed on a logarithmic scale from 1 to 100, with the higher the number, the better the performance of the dwelling. A score of 100 will for example indicate that no heating/hot water costs are required for a building. However, in very rare cases, where a dwelling is a net exporter of energy to the national grid, it can have a score greater than 100.

A Standard Assessment Procedure score of 80 or more is considered to represent an energy efficient home. Most non-new houses tend to have Standard Assessment Procedure ratings of 40-60. New houses generally achieve a SAP rating of about 80. Assessment scores are graded A-G, with A being the most energy efficient and G the least energy efficient as:

- A 92-100
- B 81-91
- C 69-80
- D 55-68
- E 39-54
- F 21-38
- G 1-20.

Mean SAP ratings for different tenures are published every year in the English Housing Survey based on a survey of approximately 20,000 homes. The latest results are based on surveys carried out in 2011/12. The SAP is periodically reviewed, the last of which was SAP09, which was applied from October 2010. An updated SAP, SAP12 has been published, although this is not currently in force for building regulations. Results presented in this report are therefore based on SAP09[6], giving a measure of the energy performance of existing new builds.

Figure 3.16 to Figure 3.18 show results for different tenure types over the period 1996/7 to 2011/12. For all and each tenure type, this shows an increase in the SAP rating of about 10 over the last 15 years, indicating an improvement in the energy efficiency of homes for all tenure types since the end of the last century. There is some sign of the SAP ratings beginning to stabilise (i.e. an s-shaped curve) as they approach a rating of 100, the point noted above where no heating/hot water costs are required for a building. This indicates that building types are becoming more energy efficient. However, conversely, this would also indicate a corresponding increase in overheating risk during the summer months, although this is dependent on whether effective ventilation has been installed, or the strategic use of natural ventilation.

[6] SAP12 is anticipated to come into force in April 2014. Future updates of this analysis will likely therefore likely be based on SAP12, and results and conclusions given in this section may as a consequence change.

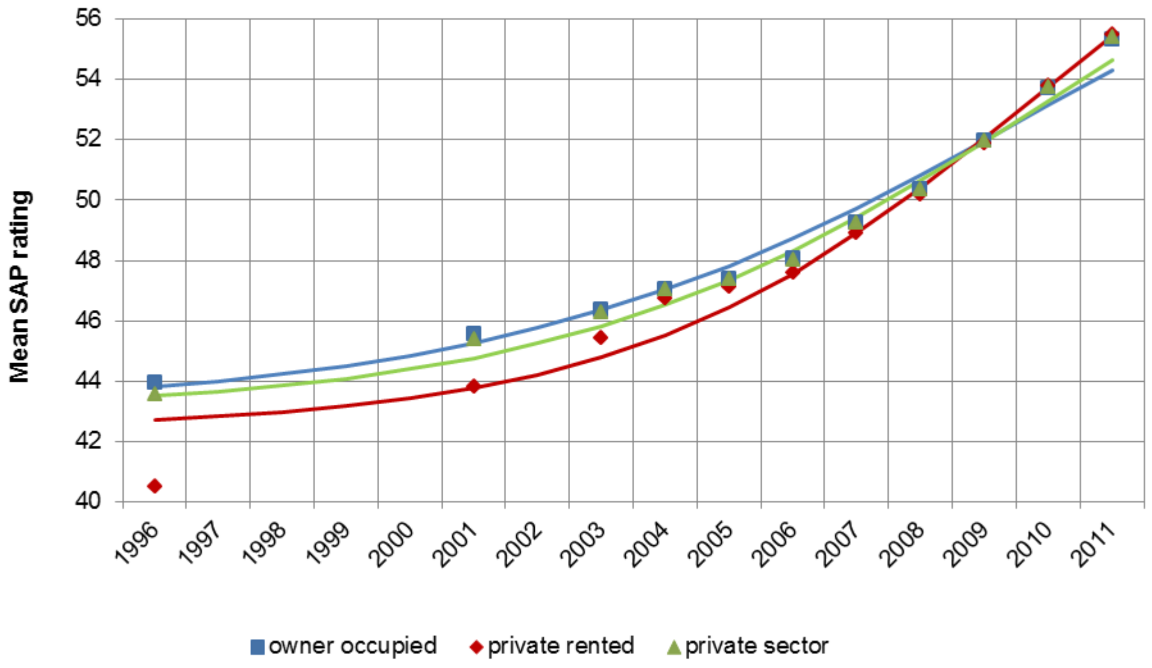

Figure 3.16: Mean SAP rating (SAP09) for England by tenure (private sector)

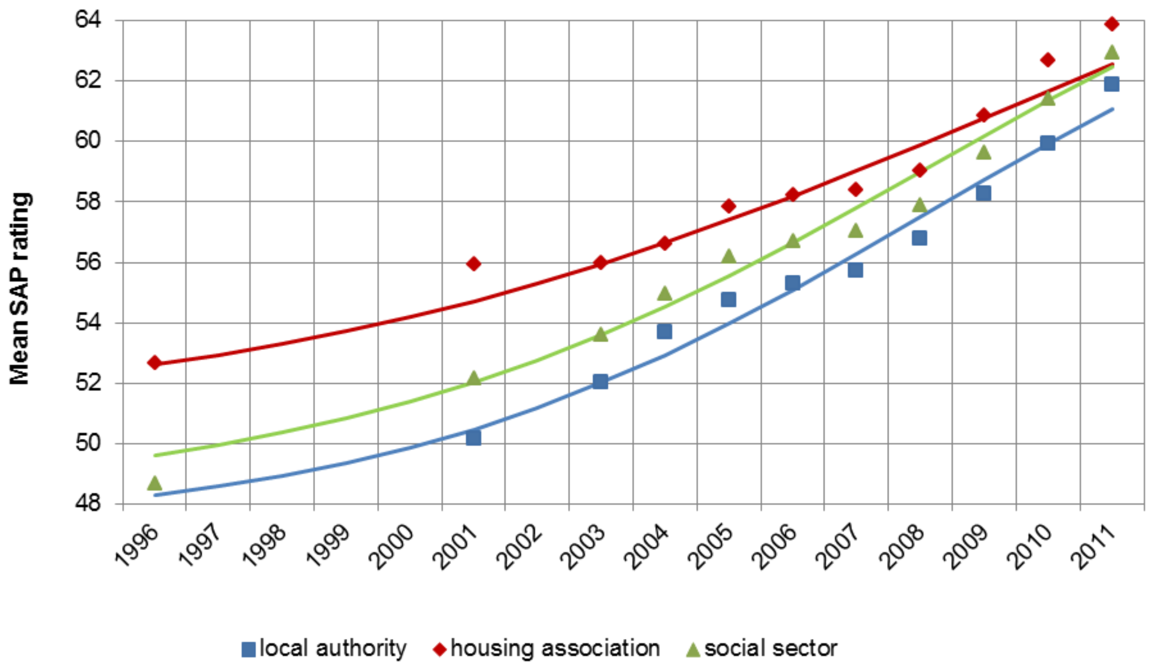

Figure 3.17: Mean SAP rating (SAP09) for England by tenure (social sector)

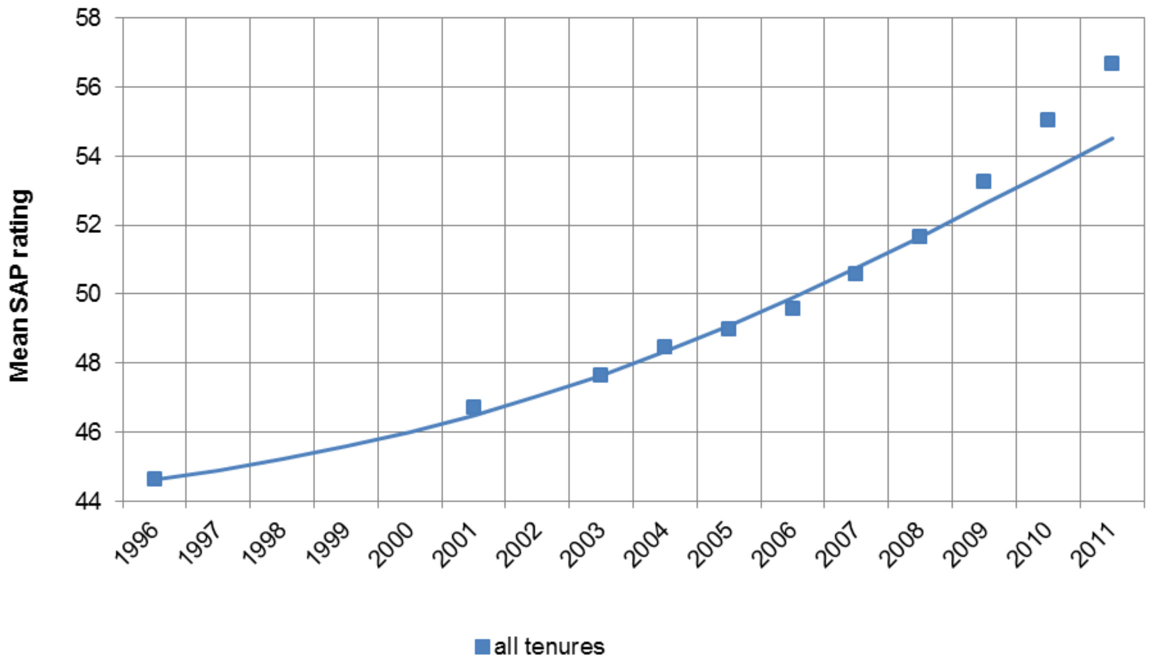

Figure 3.18: Mean SAP rating (SAP09) for England by tenure (all)

3.8. Indicator 26: Number of heat-related deaths

Introduction

During times of ambient temperatures that are above average for a geographical area (see Section 3.1), there is a notable increase in the number of hospital admissions and levels of mortality linked to these high temperatures. This is particularly the case for those individuals with pre-existing respiratory or cardio-vascular disease. Those living in urban environments in particular are at an increased risk of mortality, since these areas typically have higher heat indexes than surrounding suburban or rural areas (Lee, 1980). This is known as the "urban heat island effect" (see Section 3.2).

However, although it is accepted that there is an increase in the mortality rate during periods of high temperatures, only a few deaths are directly coded as being caused by heat (Hajat *et al.*, 2007). Therefore heat related deaths have to be estimated based on exposure-response functions linking daily mortality with temperature. The section below outlines the methodology used to estimate the number of heat related deaths based on existing epidemiological data.

Methodology

The methodology used to determine heat related deaths in this report is based on data published in Hajat *et al.*, 2014. The methodology used individual death records available from the Office of National Statistics and temperature and humidity data obtained from the British Atmospheric Data Centre to estimate deaths attributable to heat for each Government region over the period 1993-2006.

The results of this analysis are shown in Figure 3.19, which for each year shows the estimated number of deaths attributable to heat for each region. Figure 3.20 shows the combined results for England.

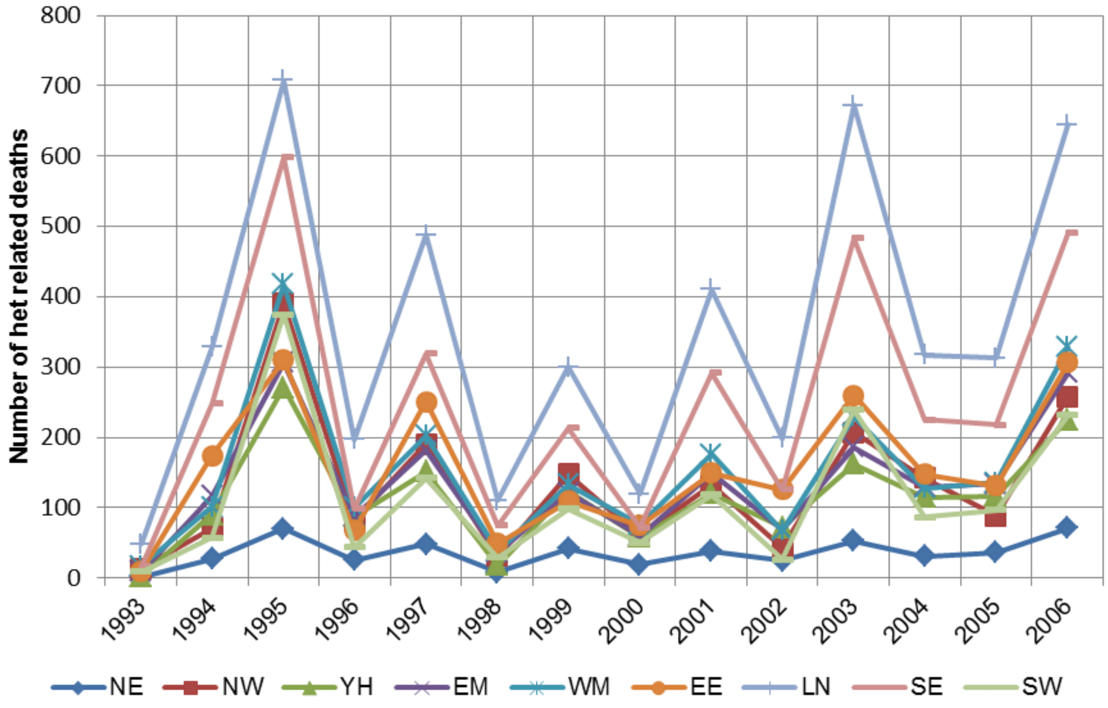

Figure 3.19: Number of annual heat-related deaths in English regions

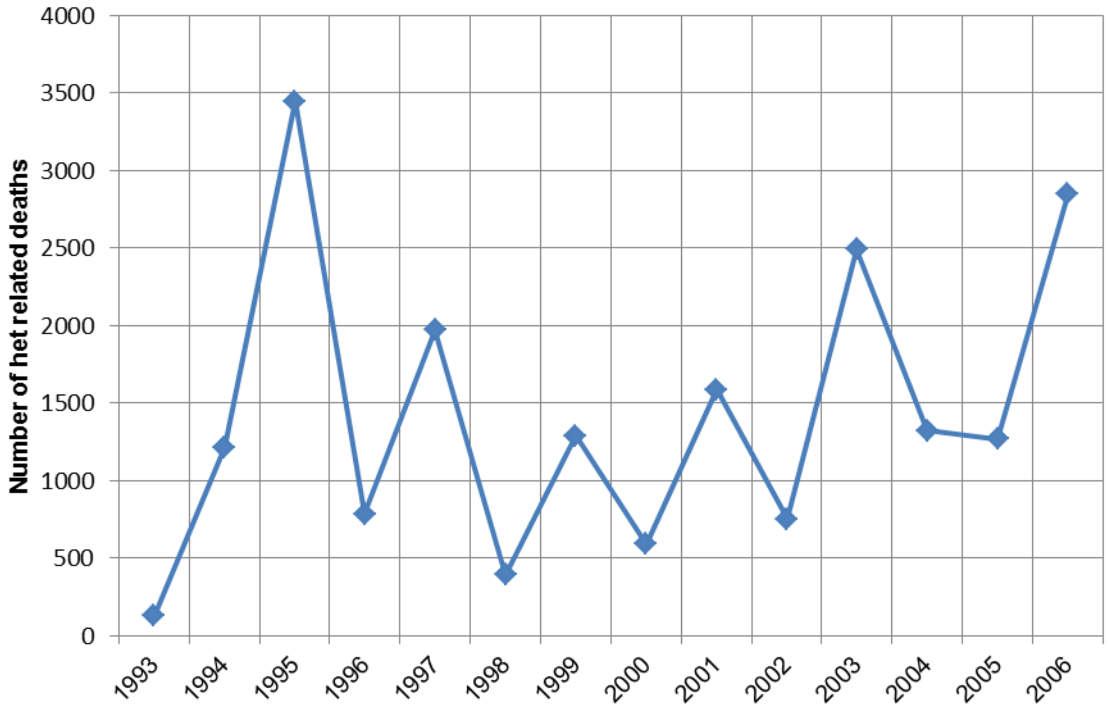

Figure 3.20: Number of annual heat-related deaths for England

From Figure 3.19, there is strong correlation between the number of deaths across each region. This is particularly the case for adjacent regions, so (for example), the strongest correlation to the North-East is to the North-West, and the strongest correlation to London is to the South-East. The correlation for London and the South-East is shown in Figure 3.22. This is not surprising given the correlation in the incidence of hot days across regions (see Section 3.1).

From Figure 3.20, there is also a noticeable variation in the number of heat related deaths on a yearly basis. For example, typically there were thirty times more deaths in 1995 when there was a hot summer, than in 1993, a year where across all regions, no noticeably high temperatures were recorded (also see Figure 3.1 and Figure 3.2). Indeed, over the period 25th July 1995 to 22nd August 1995, maximum daily temperatures were higher than the maximum recorded temperature in 1993 for most days across all regions. Similar patterns were noted for the hot summers of 2003 and 2006 (again see Figure 3.1 and Figure 3.2), particularly the two-week period 16th to 29th July 2006 where maximum daily temperatures almost without exception were higher than the maximum recorded temperature for 1993 across all regions. These hot periods also account for most of the heat related deaths in each year. The period 25th July 1995 to 22nd August 1995 for example typically accounted for more than 70% of all heat-related deaths in 1995, and more than 12% of all heat-related deaths in a one month period across the fourteen years where data was available.

3.9. Indicator 13: Age distribution of population

Introduction

In many cases, the elderly are most vulnerable to the effects of climate change, compared to younger age groups. For example those over 85 years old are particularly vulnerable to temperature related mortality (both hot and cold) (Hajat *et al.*, 2014) and are more likely to suffer from existing illnesses, as well as a range of other usually age-related syndromes. This includes poorer cardio-vascular performance, poorer temperature detection, poorer sweat production, confusion etc. In the UK, population trends show an ageing population, which indicates amplification of existing health burdens in future, putting a greater burden on the NHS.

Methodology

The 2011 census was used to determine the age distribution of the population. This was assessed separately for rural and urban areas, with the results combined to give the age distribution of the population as a whole. These results are shown in Figure 3.21, with the distribution in each band also shown in Table 3.9. From this figure, there is a clear urban/rural split from the age of about 20. This coincides with the natural initial trend of younger generations away from rural locations to urban locations after leaving home, before many of them start to return in later life. There is also relatively greater population in the 20-80 age group than for those under 20. This mainly reflects the reduction in the birth rate over the last 20 years, as well as the post-war and 1960s baby boom years. This results in a similar relative population under the age of 20 as over 60, highlighting the current significant burden on the National Health Service as a result of this large older age-group. This is something likely to worsen in future years as the current under 20 population provides the future backbone of medical care.

Earlier census' were also examined to see trends in population. This can be seen in Table 3.10 where there is an overall general increase in population. It can also be seen that there are significant increases in the number of people over 75 and especially those over 90.

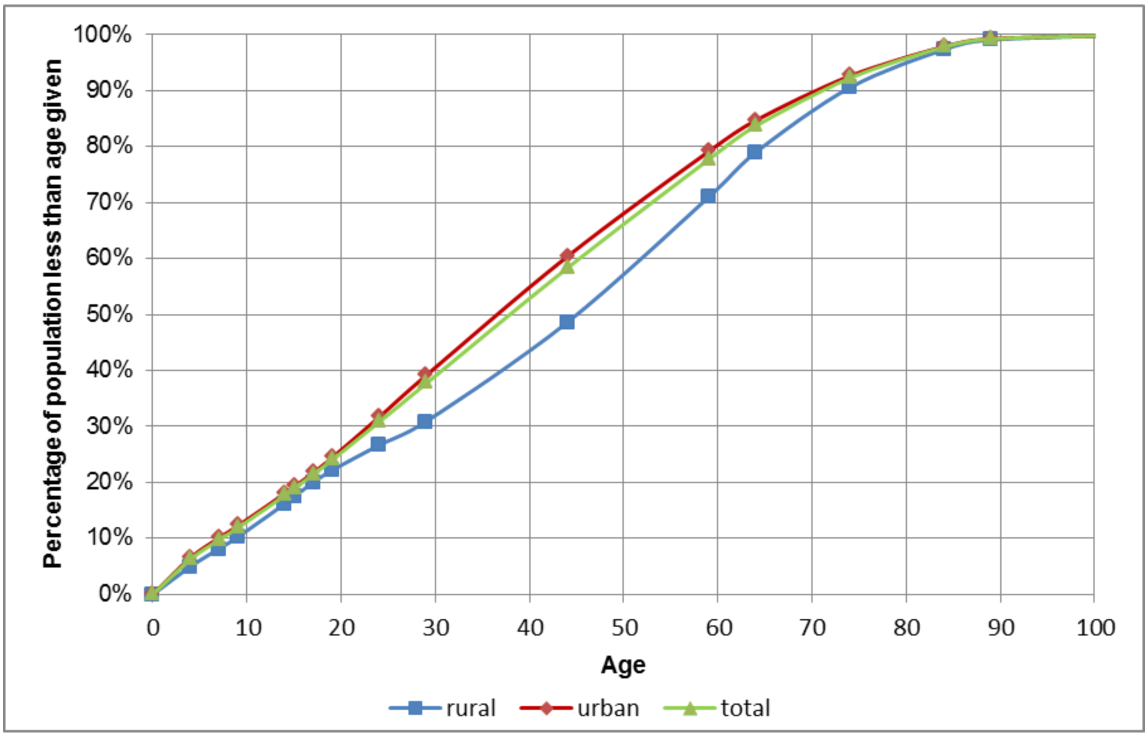

Figure 3.21: Age distribution of the population in England (based on 2011 census), showing total and urban and rural split

Table 3.9: Age distribution of the population in England (based on 2011 census), showing total (T) and urban (U) and rural (R) split (%)

Age	0 to 4	5 to 7	8 to 9	10 to 14	15	16 to 17	18 to 19	20 to 24	25 to 29	30 to 44	45 to 59	60 to 64	65 to 74	75 to 84	85 to 89	Over 90
R	5.0	3.2	2.1	5.9	1.3	2.5	2.1	4.5	4.2	17.7	22.3	8.0	11.6	6.8	1.7	0.9
U	6.5	3.5	2.2	5.8	1.2	2.5	2.7	7.3	7.5	21.3	18.8	5.6	7.9	5.3	1.4	0.7
T	6.3	3.4	2.2	5.8	1.2	2.5	2.6	6.8	6.9	20.6	19.4	6.0	8.6	5.5	1.5	0.8

Table 3.10: Age distribution of population in England from the 1991, 2001 and 2011 Census (in thousands)

Year	Age 0 to 4	Age 5 to 9	Age 10 to 14	Age 15 to 19	Age 20 to 24	Age 25 to 29	Age 30 to 44	Age 45 to 59	Age 60 to 64	Age 65 to 74	Age 75 to 84	Age 85 to 89	Over 90	Total
1991	3,130	2,941	2,813	3,020	3,534	3,768	10,016	7,876	2,404	4,221	2,614	517	202	47,056
2001	2,926	3,123	3,229	3,033	2,953	3,269	11,128	9,280	2,392	4,103	2,751	638	316	49,139
2011	3,318	2,973	3,081	3,340	3,595	3,651	10,944	10,277	3,172	4,552	2,928	776	404	53,012

3.10.Indicator 30: Trends in very wet days

Introduction

An increase in very wet days can have a range of health impacts. This could lead to an increased risk of flooding, resulting in an increased risk of death, injury and mental health effects, or an increased risk of communicable diseases, particularly for the more vulnerable members of society (e.g. the young, elderly, disabled etc.). More wet days would increase the risk of damp in buildings, with a consequent increased risk of respiratory symptoms related to fungi. This is particularly the case for alternaria, which can cause a life-threatening asthma attack, particularly after heavy rainfall events. Increased risk of hypothermia could also be a problem, particularly for those exposed to heavy rain, or trapped in floodwaters for an extended period of time.

All of these effects could result in increased pressures on the emergency services, particularly during extreme events as a result of both number of incidents, as well as transport issues resulting from flooding. For diseases, this could also lead to increased pressures in the following weeks as these become apparent.

Methodology

To assess this indicator, mean observed gridded daily rainfall data was obtained from the Met Office website over the period 1960-2011 (see Perry and Hollis, 2006). This data, covering England at a 5 × 5 km resolution, gave the number of single-day rainfall events that exceed the 1961-1990 90th and 99th percentile both seasonally and annually. These records were then combined for the different regions and accounting for population using the same methodology as outlined for temperature (see Section 3.1).

Results

Figure 3.22 to Figure 3.25 show the number of population-weighted single-day rainfall events that exceed the 1961-1990 90th percentile for the four seasons. From these results, there is no noticeable trend for any of the seasons, and few years where there is significantly more or less heavy rainfall days than other years. Noticeable exceptions are the seasons corresponding to the summer droughts of 1976 and 1995, and the 2000 autumn and 2007 summer floods. Previous studies have suggested an increase in rainfall in the winter months, and a reduction in rainfall in the summer months, Osborne and Hulme (2002) and Jenkins (2008). Osborne and Hulme (2002) considered heavy rainfall events, and Jenkins (2008) all rainfall events. These studies though relate to the UK, not England, and were considered over a shorter time period (1961-2000). Reported changes in rainfall over these periods are dominated by changes in rainfall patterns over Scotland, and these vary noticeably when considering different time periods. Considering the same time periods considered by Osborne and Hulme (2002) and Jenkins (2008) using the same methodology considered in this study appears to give broadly similar results to these studies when considering England only. This suggests that trends for wetter winters and drier summers for England at least over the period 1960-2011 are not as great as has previously been suggested. Even though this analysis is based on populated weighted averages for rainfall, a repeat of the analysis (not shown) based on area weighted values suggested negligible change in the calculation of trends.

There is little variation in the means for all four seasons, although a larger than average variability in London, and a less than average variability for the North-West. These results appear inconsistent with the Met. Office own published data on heavy rainfall days, which shows significantly greater levels of rainfall in the North-West[7], an effect little affected by using a population weighted assessment.

[7] http://www.metoffice.gov.uk/climate/uk/averages/ukmapavge.html

Between regions, the number of heavy rainfall days are noticeably less correlated than hot days (see Section 3.1). However, there is relatively strong correlation between regions on the east of the country (East, South-East and London), and little correlation between the North-West and the East and London.

Figure 3.28 amalgamates all of these results for England, showing the number of population-weighted single-day rainfall events that exceed the 1961-1990 90th percentile annually and for all four seasons. This shows little correlation between seasons in individual years, and as for the regions, little trend in the number of heavy rainfall events.

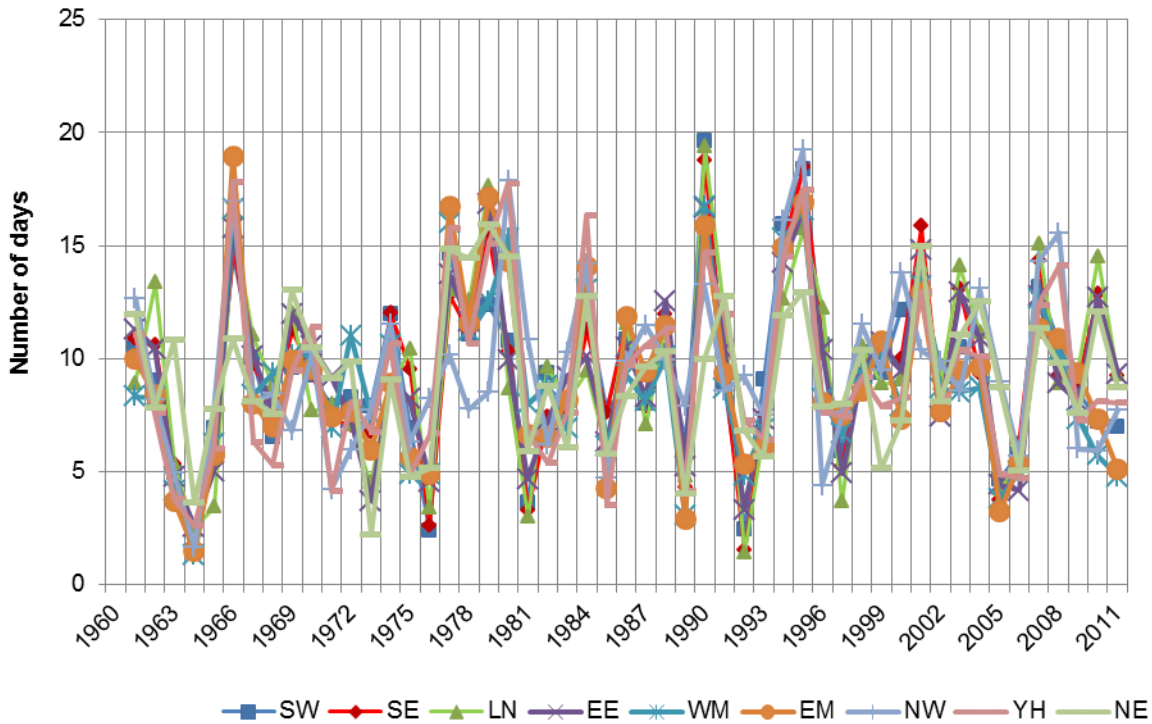

Figure 3.22: Number of single-day rainfall events that exceed the 1961-1990 90th percentile (winter) for English regions

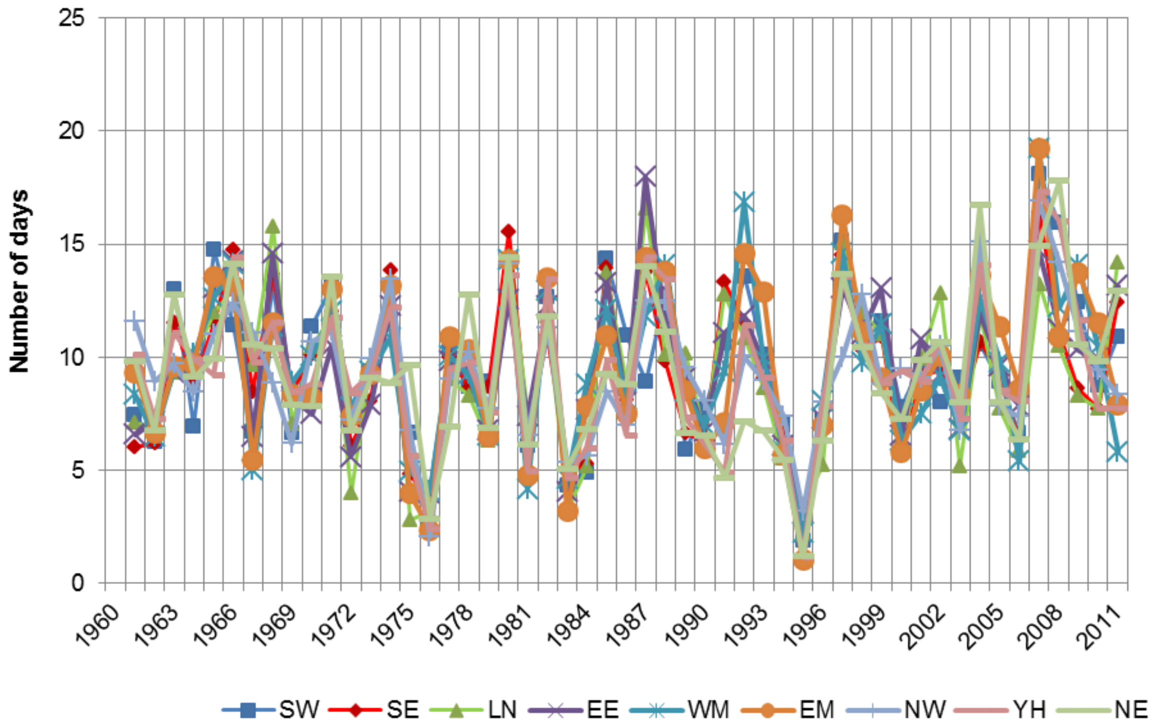

Figure 3.23: Number of single-day rainfall events that exceed the 1961-1990 90th percentile (summer) for English regions

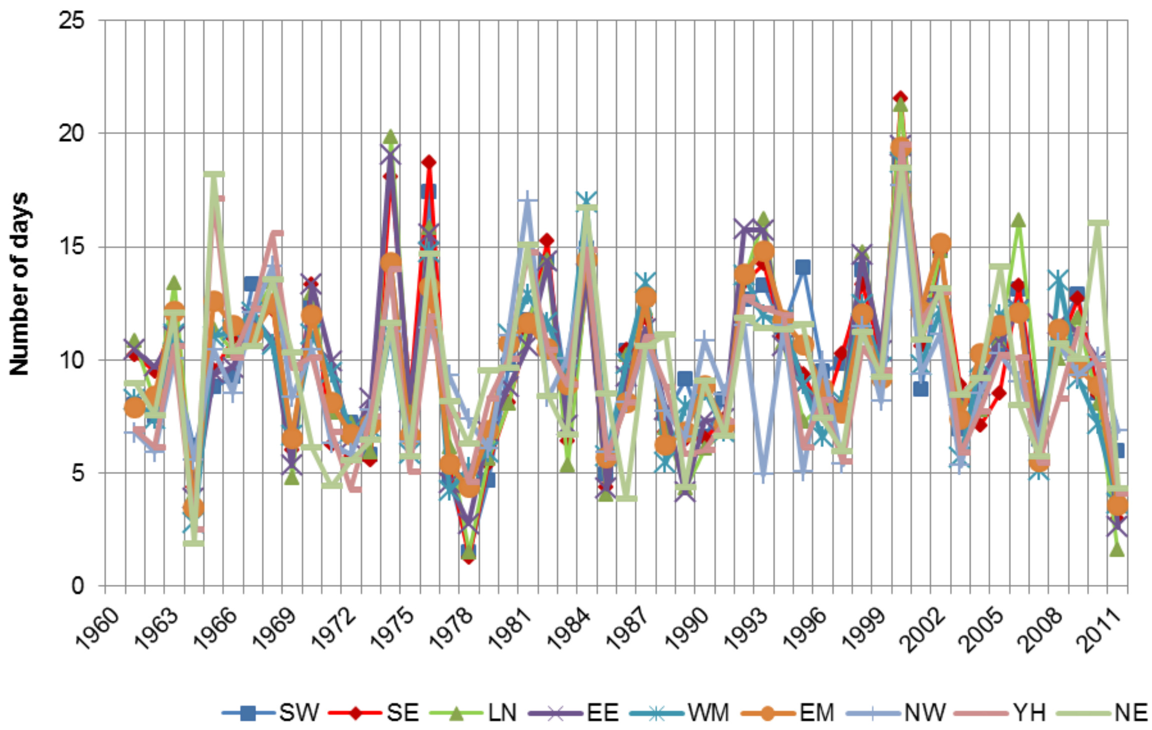

Figure 3.24: Number of single-day rainfall events that exceed the 1961-1990 90th percentile (autumn) for English regions

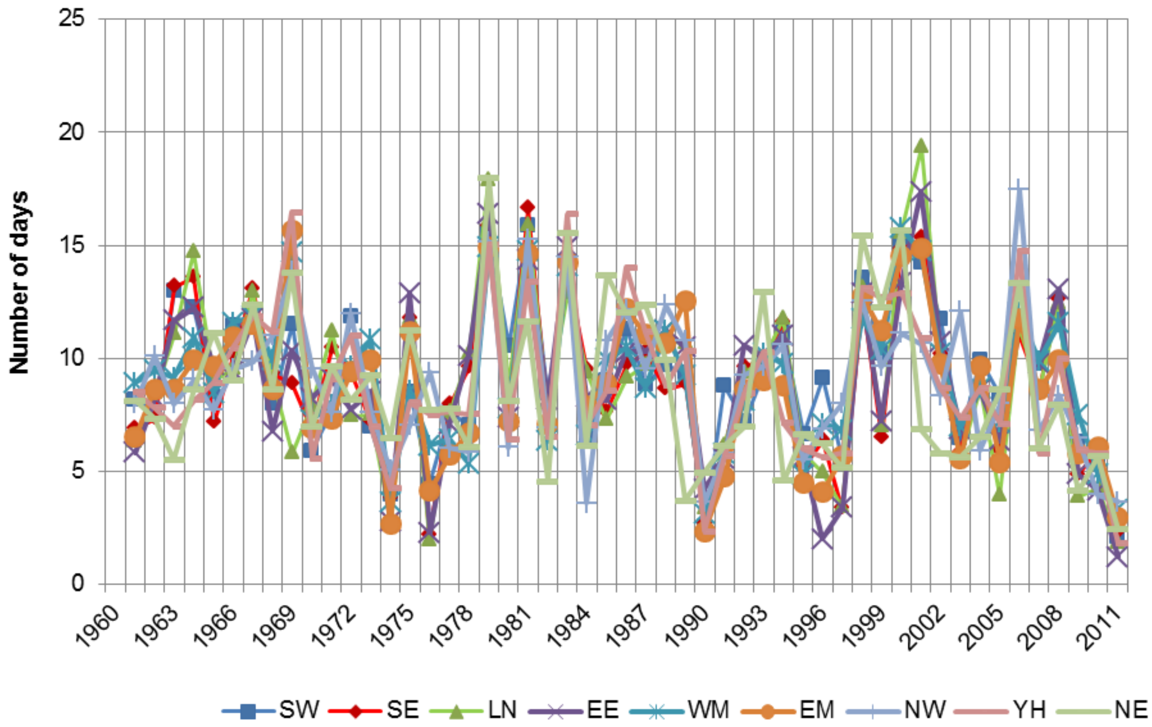

Figure 3.25: Number of single-day rainfall events that exceed the 1961-1990 90th percentile (spring) for English regions

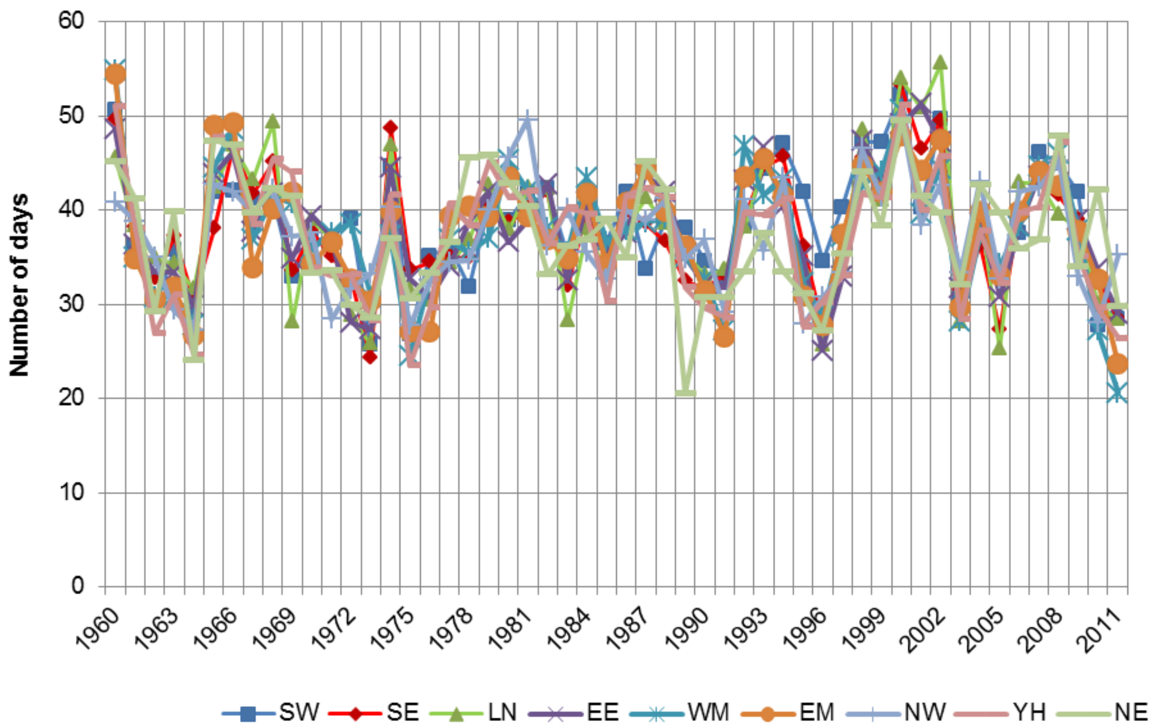

Figure 3.26: Number of single-day rainfall events that exceed the 1961-1990 90th percentile (annual) for English regions

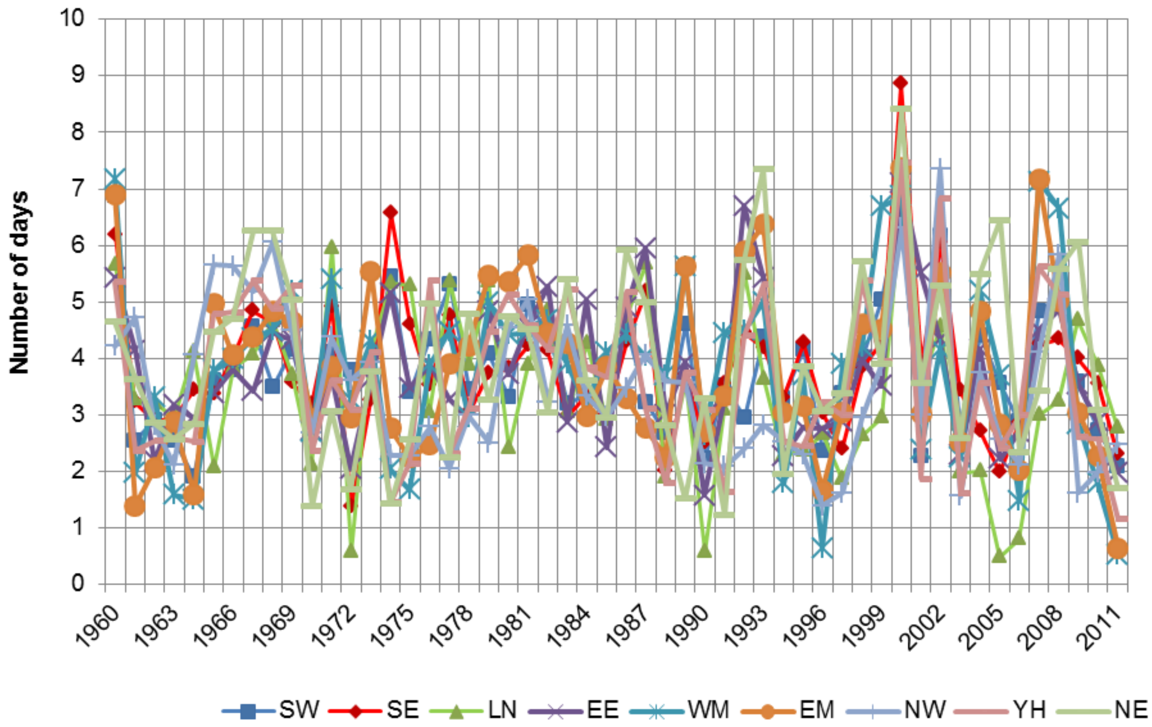

Figure 3.27: Number of single-day rainfall events that exceed the 1961-1990 99th percentile (annual) for English regions

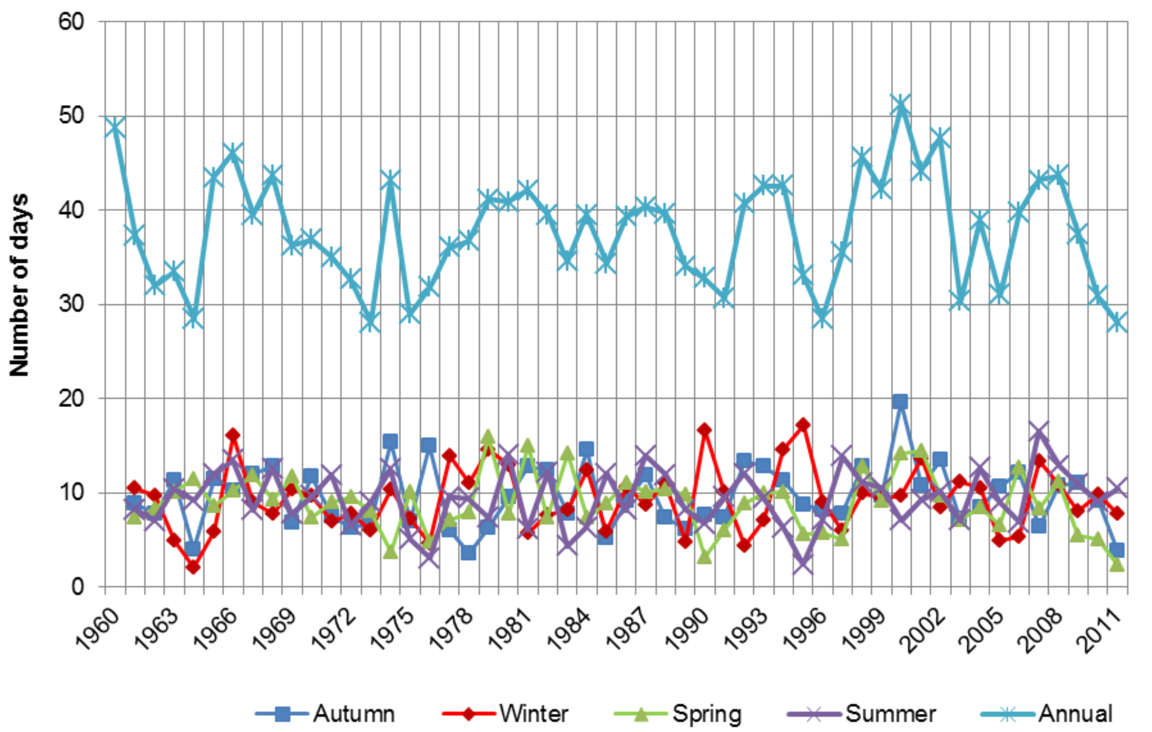

Figure 3.28: Number of single-day rainfall events that exceed the 1961-1990 90th percentile for England

The winter season is defined over the December of the previous year, and the January and February of the current year. This means that the sum of the total rainfall over all four seasons for a year will not equal the total annual rainfall, which is measured over the January to December period for that year. The December of 1989 for example was a very wet month, with a number of very heavy rainfall days. As a result, the number of single-day rainfall events above the 99th percentile for England in the winter of 1990 (which is not shown) was greater than the number of single-day rainfall events above the 99th percentile for England in 1990.

3.11. Indicator 33: Number and location of vulnerable people that would need special assistance in the case of an extreme weather event

Introduction

In the case of an extreme weather event, there are a number of people that are likely to need special assistance. For this report, a number of groups of vulnerable people have been considered, and these are outlined below, together with the sources of data.

- Schoolchildren:
  - Available from the 2013 School Level Census.
- Under 5's and over 75s:
  - This has been assessed for the indicator of vulnerable people in urban areas (see Section 3.5).
- People in nursing homes:
  - The number of patients in a nursing home is available for 2010 and 2011 for each Strategic Health Authority from GP registrations.
- People in hospitals (assessed as number of hospital beds):
  - Hospitals tend to operate at a maximum capacity, cancelling and re-scheduling operations as appropriate to match this level. This has therefore been assessed as the number of hospital beds.
- People with a disability:
  - The number of disability allowance claimants is available for 2011 for each Strategic Health Authority from GP registrations.
- People in temporary accommodation:
  - This is one of the indicators developed as part of the Public Health Outcomes Framework (see Section 3.16). Although it is not known why these people are in temporary accommodation, it is considered by the Public Health Outcomes Framework as a determinant of mental health, which may or may not be a consequence of mental illness.

Results: Number of school children

Figure 3.29 shows the number of pupils in schools by local authority in 2013 and Figure 3.29 (right map) shows the proportion of pupils relative to the total population in each local authority (district and unitary authority). The total number of pupils for the whole of England in 2013 was 8,226,760. The areas where there are higher numbers of pupils are London, Cornwall, Wiltshire, a band running from the Mersey to the Humber and Durham. When taken as a proportion of the total population these areas are less marked, with

most areas falling in the middle range of 12 to 16%. Areas with a higher proportion extend around London and the centre of England.

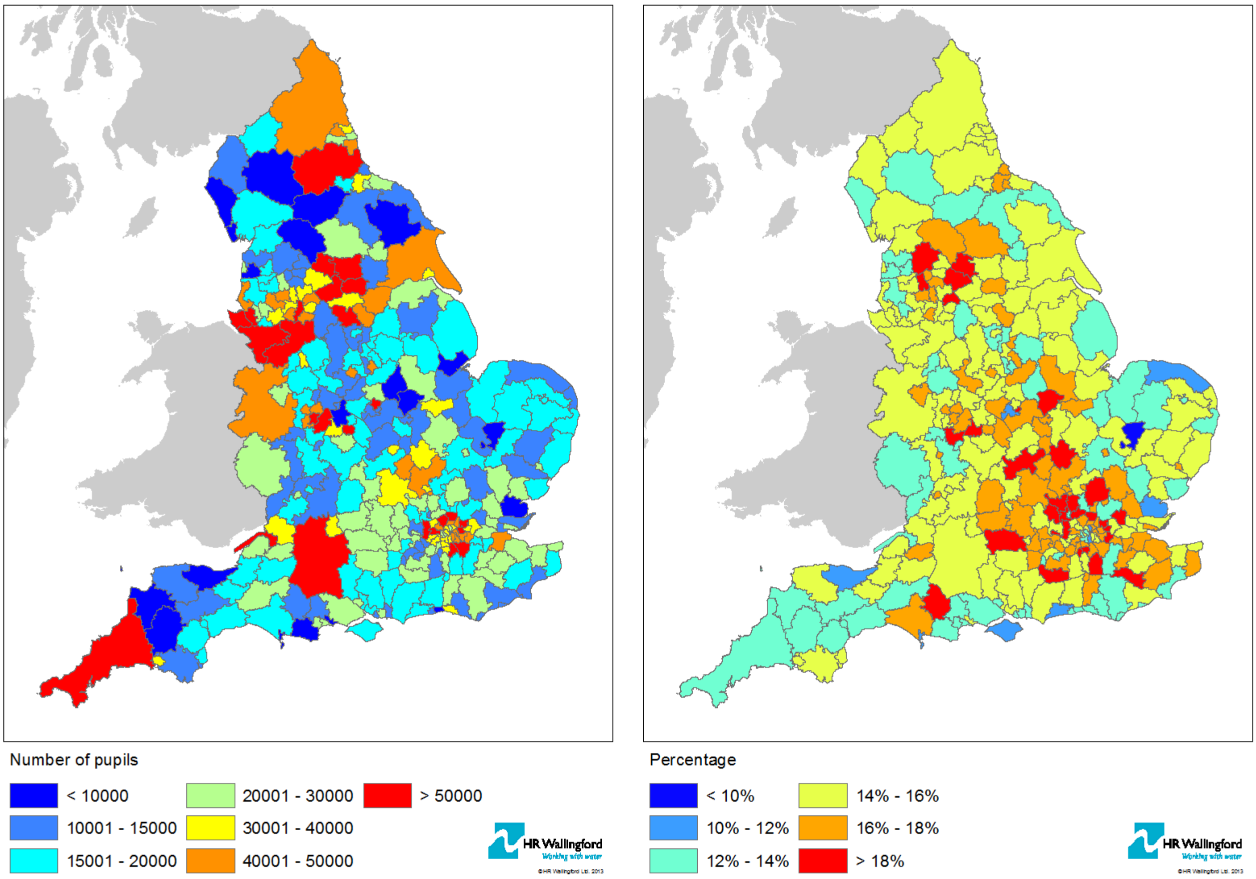

Figure 3.29: Number of pupils by Local Authority in schools by 2013 (left) and number of pupils in schools as a percentage of total population (right)

Results: Number of people under 5 and over 75

The number of people under 5 and over 75 was assessed under Indicator 7 (Section 3.5), the number of vulnerable people in urban locations. This has therefore not been repeated in this section.

Results: Number of people in nursing homes

Figure 3.30 and Figure 3.31 show the number of people in nursing homes as a proportion of the population and as absolute numbers for each Primary Care Trust for 2010 and 2011. The total number of nursing home patients in England for 2011 was 281,424. The areas where the least number of people are in nursing homes is generally centred in and around London, with a few other areas predominantly in central England. The areas where the largest number of people are in nursing homes are generally in Strategic Health Authorities on the coastline, with Shropshire being the one noticeable exception. There has been little change between the number of people in a nursing home between 2010 and 2011. The two possible exceptions to this are for Mid Essex and North Tyneside, which have each experienced a 0.14% increase in the proportion of people in a nursing home over this two year period.

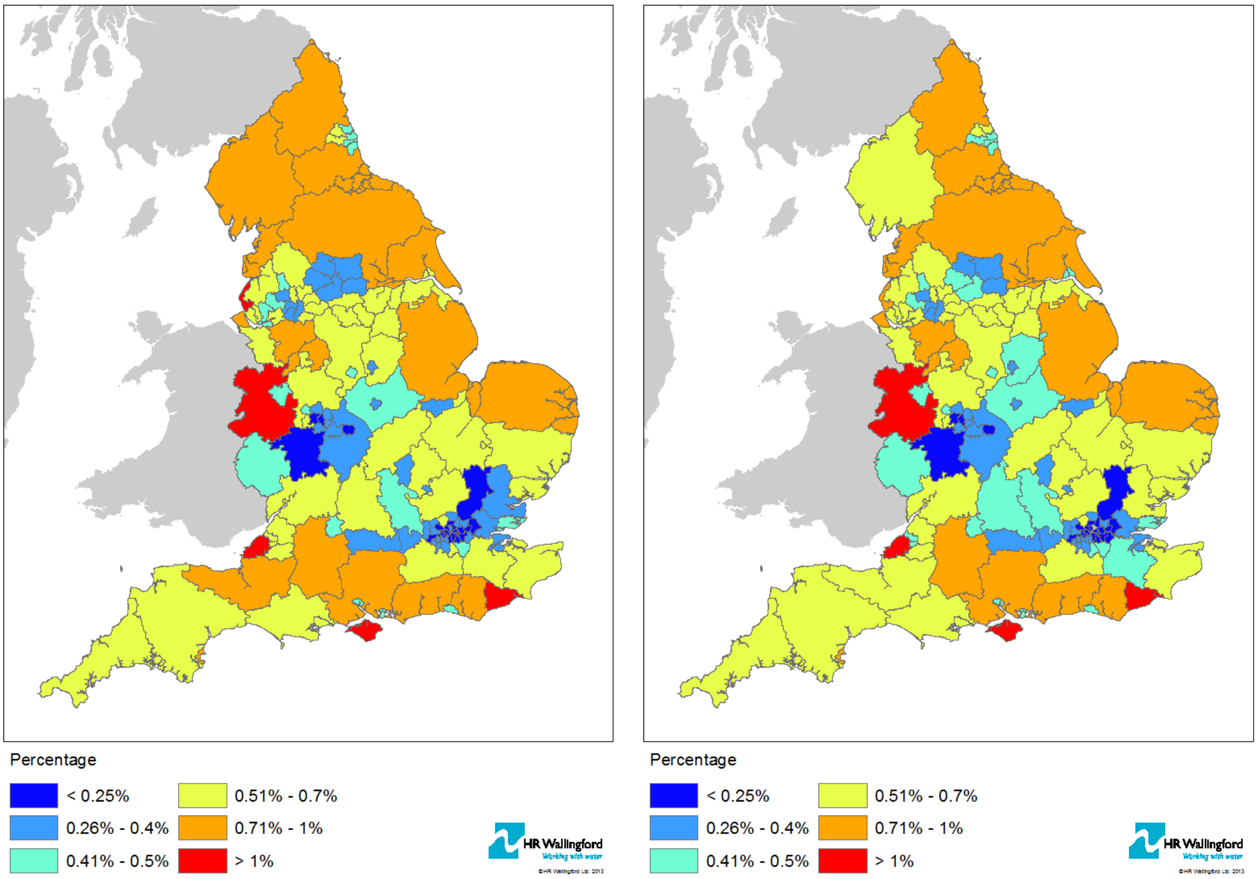

Figure 3.30: Number of people in nursing homes as a percentage of registered patients in the Primary Care Trust area (2010 left and 2011 right)

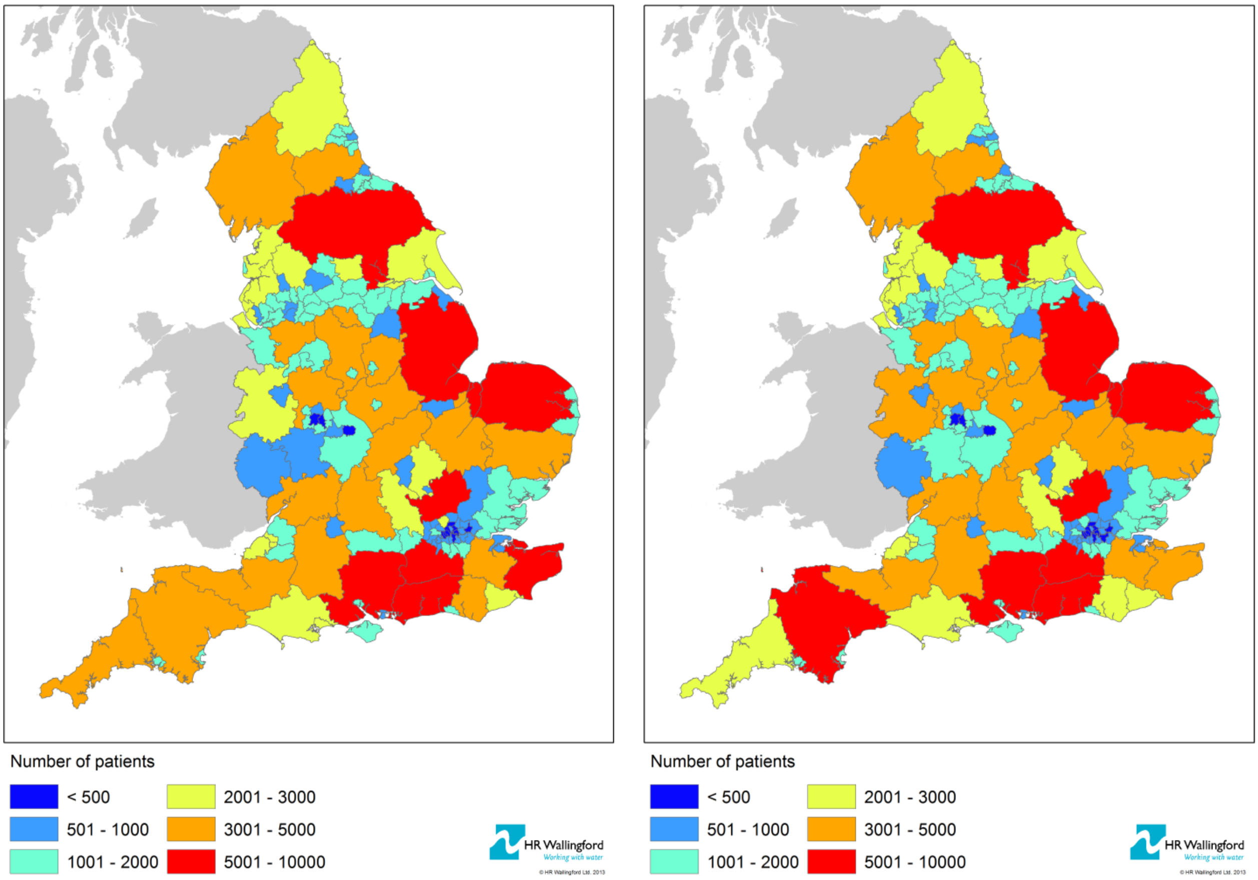

Figure 3.31: Number of people in nursing homes in Primary Care Trust area (2010 left and 2011 right)

Results: Number of hospital beds

The maps show that the area with the fewest beds is the South Central Strategic Health Authority and the areas with the most beds are London and the North West. When compared to the number of occupied beds this shows that although London has the highest number of beds it is also the area with the highest demand for beds with a 91% occupancy rate. The North East has one of the lower numbers of total beds but has a greater free capacity with an occupancy rate of 81%. The total number of available beds in England is 281,424, while the total number of occupied beds in England is 126,390 for 2013.

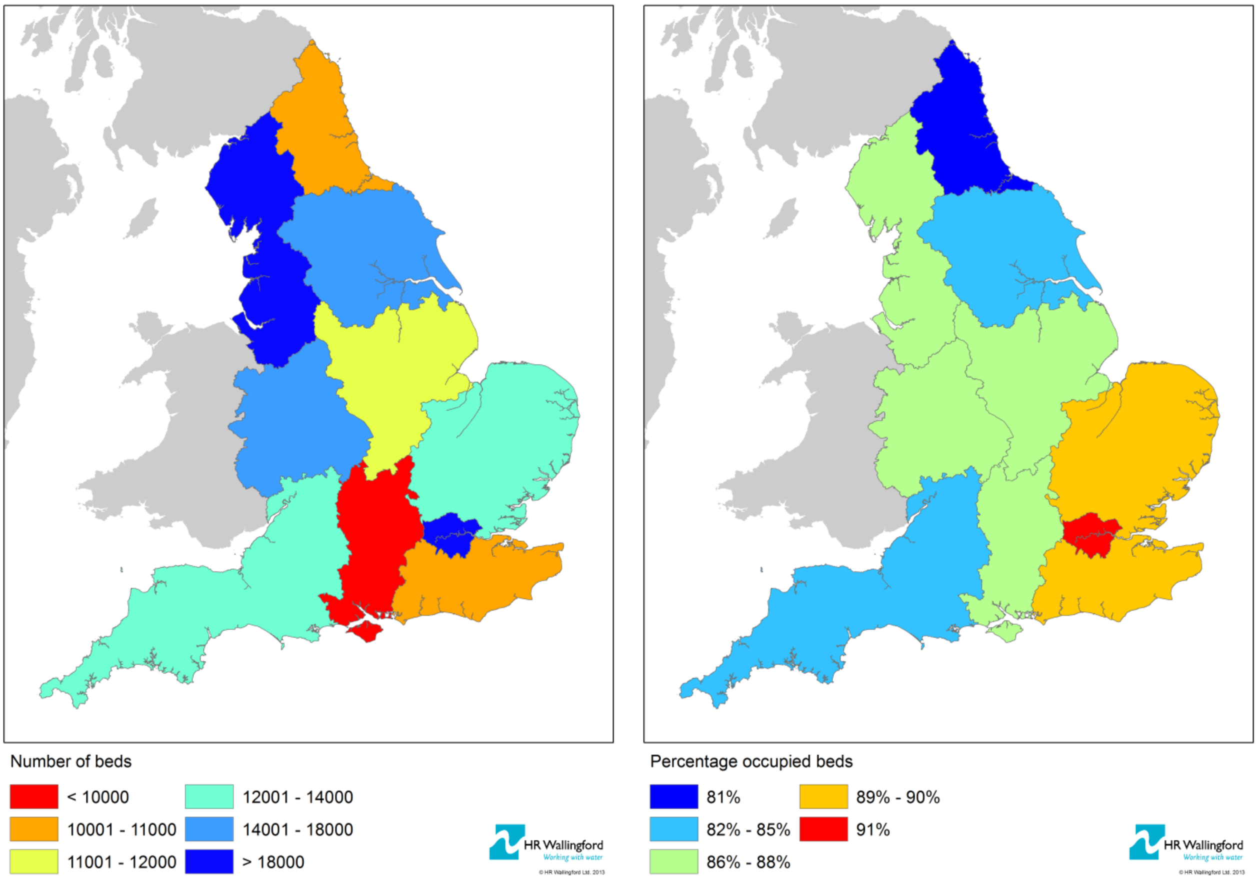

Figure 3.32: Number of beds in hospitals 2013 (left) and percentage of occupied beds 2013 (right) by Strategic Health Authority

Results: Number of people with a disability

Figure 3.33 shows the number of disability living allowance claimants in 2011 by Primary Care Trust (totals and by population). From this figure, there is a general north-south divide from approximately The Wash to The Dee Estuary. South of this line, typically less than 5% of the population by Primary Care Trust received a disability living allowance in 2011, which was typically more than 5% north of this line. The largest number of disability living allowance claimants were typically in large urban areas, particularly around Merseyside. The smallest number of disability living allowance claimants was typically in more rural areas, particularly in regions east and west of areas centred around Oxfordshire, Berkshire, Buckinghamshire and Surrey. The total number of people receiving Disability Living Allowance in England in 2011 was 2,655,050.

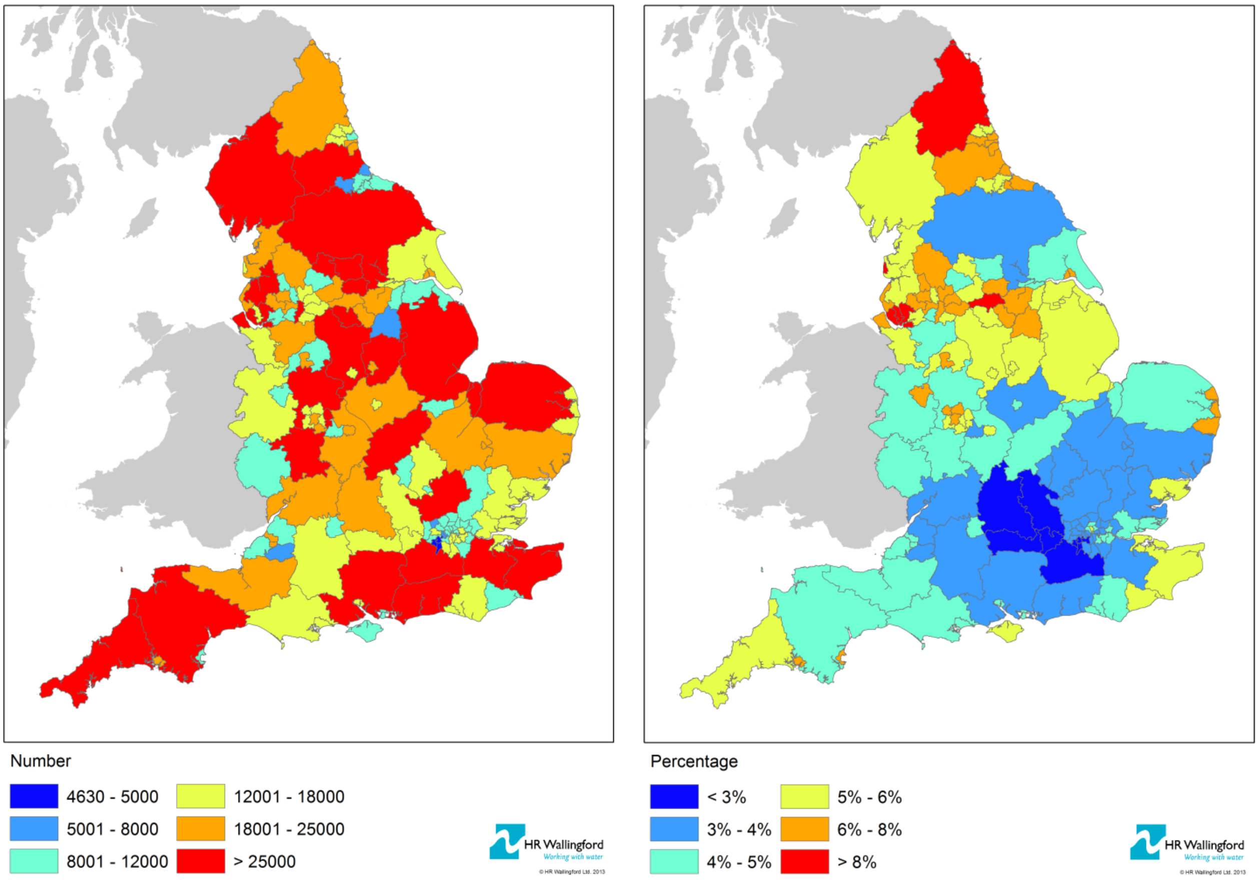

Figure 3.33: Proportion of people receiving Disability Living Allowance by Primary Care Trust in 2011

Results: Number of people in temporary accommodation

This indicator was chosen to consider the number of people in temporary accommodation due to flooding or extreme weather events. However, it is not possible to identify these sub-groups, so this indicator has been considered as the number of people in temporary accommodation as a whole. However, people living in temporary accommodation for whatever reason may need assistance to move, so could be considered vulnerable.

Figure 3.34 shows the number of people in temporary accommodation for two time-periods, 2010/11 and 2011/12. These figures suggest an approximate north-south divide, with typically less than 0.5% of households in temporary accommodation north of a line running from The Wash to the Severn Estuary, and greater than 0.5% of households in temporary accommodation south of this line. There is no noticeable clustering of people in temporary accommodation in the larger cities, apart from the obvious exception of areas in and around London. People in temporary accommodation around London is typically at least 5%, the only areas in England where the number of people in temporary accommodation is as high as this. These figures are in excess of 30% in Haringey in North London, and 10% and above in many London Local Authorities, particularly in north and east London. Noticeable changes in numbers in temporary accommodation were a fall from 33.6% to 30.0% in Haringey and from 29.5% to 24.5% in Newham over the period 2010/11 to 2011/12. However, the fall in Newham was accompanied by a similar rise in the adjacent Authority of Barking and Dagenham over the same time period.

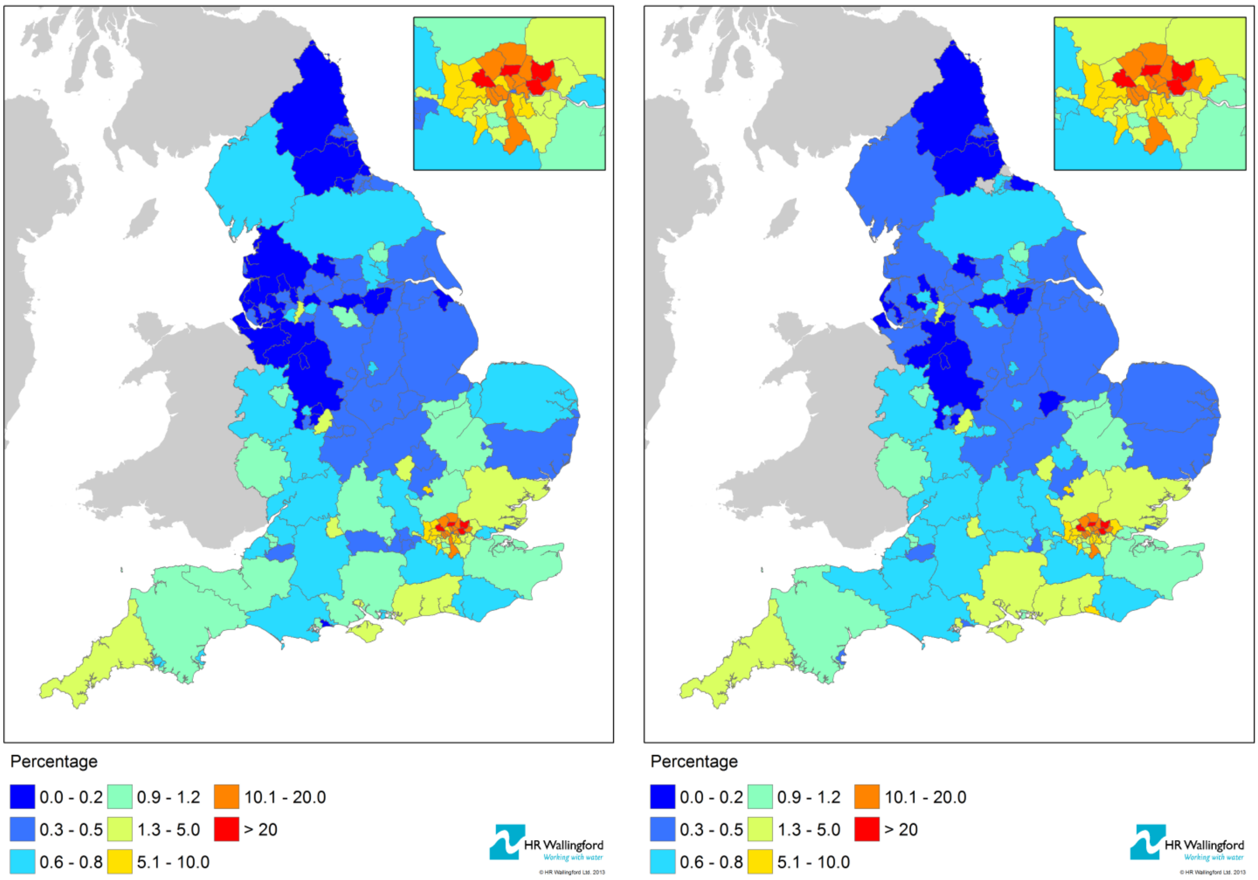

Figure 3.34: Households in temporary accommodation by county and unitary authority (2010/11 left, 2011/12 right)

3.12. Indicator 35: Number of properties/people signed up to the Environment Agency's flood warning service

Introduction

For the 2012 ASC progress report, HR Wallingford (2012) assessed the number of properties registered with the Environment Agency's Flood Warning Direct (FWD) service. This was assessed for two dates, which were 03/06/2008 and 02/01/2012 (this was assumed to apply to 2011). The results of this analysis has therefore been replicated in this report, with no additional analysis carried out. However, as this report is mainly concerned with the number of people affected, an assumption of an average of 2.4 people per residential property has been used, as published in Macrory (2012) (also see Appendix D).

This section summarises the results of the analysis previously carried out. Further results and details are given in HR Wallingford (2012).

Results

The results are shown in Table 3.11. Also shown in this table for comparison are the latest figures for 2013 based on the values published in the Environment Agency Annual Report and Accounts, 2012-2013. Over the 3.5 year period 2008-2011, there has been an increase of over 120,000 properties, equivalent to almost 300,000 people onto the Flood Warning Direct (FWD) service. This has stabilised in recent years, and current figures show a slight reduction since 2011 of just over 20,000 properties. Since 2008, the percentage of properties/people registered to the FWD service has increased from about 17% to 22-23%. Overall, about 58% of properties are now either registered on the FWD service, or on the Environment Agency Flood Warning System (FWS). There are also another 4% of properties that have either declined or cancelled the flood warning service from the Environment Agency.

It is likely that the vast majority of residential properties registered with the FWD will be in the significant and moderate flood likelihood bands (see Section 3.13), which represent about 890,000 properties (as discussed in more detail in HR Wallingford, 2012).

Table 3.11: Uptake of the Environment Agency Flood Warning Direct (FWD) service and number of properties on the Environment Agency Flood Warning System (FWS)

Year	Households in the natural floodplain	FWD fully registered properties	Properties on the FWS system	As a percentage of those within the natural floodplain	
				FWD	FWD+FWS
2008	1,778,375	304,159	-	17%	-
2011	1,831,158	427,197	-	23%	-
2013	1,838,176	406,461	655,400	22%	58%

The proportions of properties that are registered with the FWD are shown in Figure 3.35 by Local Authority area for 2008 and 2011 respectively. The proportions are generally highest in the more rural parts of the south-east and the north. The proportions are relatively low in urban areas and areas where a high proportion of land is at risk of flooding (particularly the fenlands, south and east Yorkshire, and north Somerset). Comparison of the 2008 and 2011 data shows a distinct increase in the proportion of properties in many areas.

In addition to the number of registered properties, there are also about 33,000 people who are fully registered to receive warnings in areas where they do not own a property. It should also be appreciated that

FWD is not the only method of disseminating flood warnings. Whilst it is the primary method, some areas have other local arrangements such as sirens, flood warden schemes and media broadcasts.

Since 2008, the Environment Agency have introduced Extended Direct Warnings which augments the number of properties that are able to receive a FWD service by obtaining contacts numbers from the emergency services database for unregistered properties. This accounts for a further 688,000 properties in England. Furthermore, in the tidal Thames area, FWD warnings are not appropriate; here the Environment Agency uses mass media methods to issue warnings.

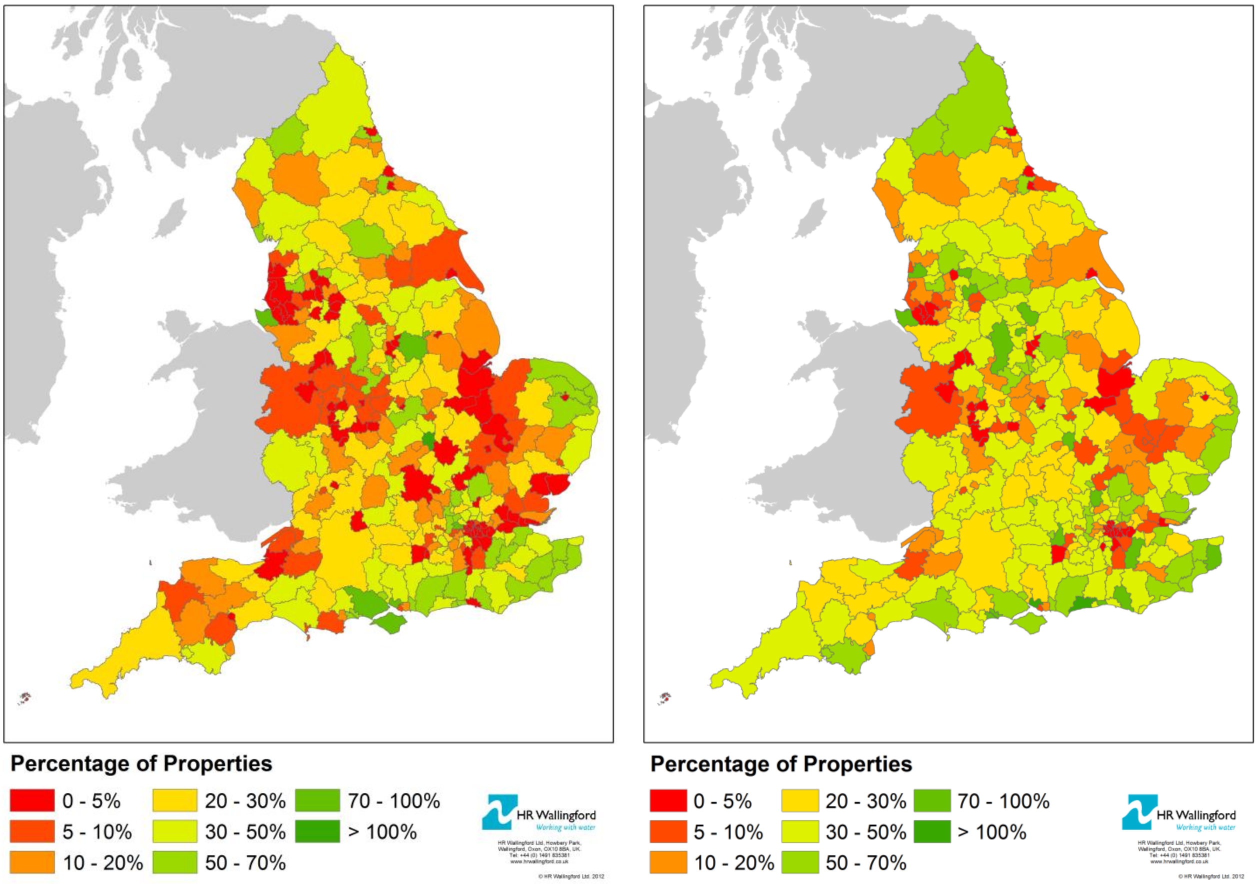

Figure 3.35: Proportion of properties in flood risk areas that receive Environment Agency flood warnings, 2008 (left) and 2011 (right)[8] by local authority.

[8] Note: There are a small number of Local Authorities where the percentage of properties fully registered to receive EA Flood Warnings Direct exceeds 100% of the number of properties in the natural floodplain. This may be either where properties outside of the floodplain are registered or where certain properties may be registered more than once under different occupiers.

3.13. Indicator 35a: Number of properties/people at significant risk of flooding

Introduction

For the 2012 ASC progress report, HR Wallingford (2012) assessed the number of properties located within the fluvial, tidal and coastal floodplains with different likelihoods of flooding, taking into account the presence and performance of any existing flood defence infrastructure. This was based on the Environment Agency's best available national data on flood risk, the National Flood Risk Assessment (NaFRA) which defines the likelihood of the onset of flooding from rivers or the sea based on NaFRA 2011 bands. This indicator has therefore been replicated in this report, with no additional analysis carried out. Results are presented for both residential and non-residential property, although comments on the results are mainly restricted to residential properties. Considering the number of people at significant risk of flooding, this has assumed an average of 2.4 people per residential property as discussed in Section 3.12.

This section outlines the results of the analysis previously carried out, with brief details of the methodology. Full details of the methodology are given in HR Wallingford (2012).

Methodology

The results of this analysis are defined for categories of flooding probability as defined by the National Flood Risk Assessment (2011)[9]:

- **Low**; 0.1% to 0.5% (1 in 1000 to 1 in 200 chance in any given year);
- **Moderate**; 0.5% to 1.3% (1 in 200 to 1 in 75 chance in any given year);
- **Significant**; more than 1.3% (more than 1 in 75 chance in any given year).

Results

The results for England are shown in Table 3.12. These results show that in 2011 about 8% of residential properties were in the floodplains. About 1.3% of residential properties were at a 1.3% (1 in 75 chance in any given year) or greater risk of flooding, and about 4.3% of residential properties were at a 0.5% (1 in 200 chance in any given year) or greater risk of flooding.

[9] These categories were changed by the Environment Agency in 2013 to a five band classification.

Table 3.12: Number of properties within areas of different flood likelihood for England

Results expressed in thousands		Residential		Non-residential		All property	
Year	**Type**	**count**	**%**	**count**	**%**	**count**	**%**
2001	Significant	260	1.2%	35	3.0%	295	1.3%
	Moderate	523	2.5%	50	4.3%	573	2.6%
	Low	865	4.1%	68	5.8%	933	4.2%
	Total property in England	21,038	100.0%	1,171	100.0%	22,209	100.0%
2008	Significant	287	1.3%	35	3.2%	323	1.4%
	Moderate	572	2.6%	50	4.5%	622	2.7%
	Low	950	4.3%	65	5.9%	1,016	4.3%
	Total property in England	22,266	100.0%	1,106	100.0%	23,372	100.0%
2011	Significant	298	1.3%	37	3.2%	335	1.4%
	Moderate	590	2.6%	52	4.5%	642	2.7%
	Low	976	4.3%	70	6.0%	1,045	4.4%
	Total property in England	22,679	100.0%	1,151	100.0%	23,831	100.0%

The numbers of properties in each likelihood band are shown on Figure 3.36 and Figure 3.37 for residential and non-residential properties respectively. The results show a rise in the number of residential properties, which represent 95% of all properties by number, in each flood likelihood band. The overall rate of rise has reduced after 2008, which reflects a national reduction in new property numbers. The annual increase in overall numbers of properties per year dropped from about 0.75% in 2001-2008 to about 0.65% in 2008-2011. Overall the number of non-residential properties showed little change in the period 2001 to 2011. Figure 3.36 suggests that approximately 4.5 million people are at least at a low risk of flooding for 2011, up from about 4.0 million in 2001. Of these, approximately 0.7 million (as of 2011) are at significant risk of flooding. This has increased by approximately 3.6% over the period 2001-2008, and 10.6% over the period 2008-2011.

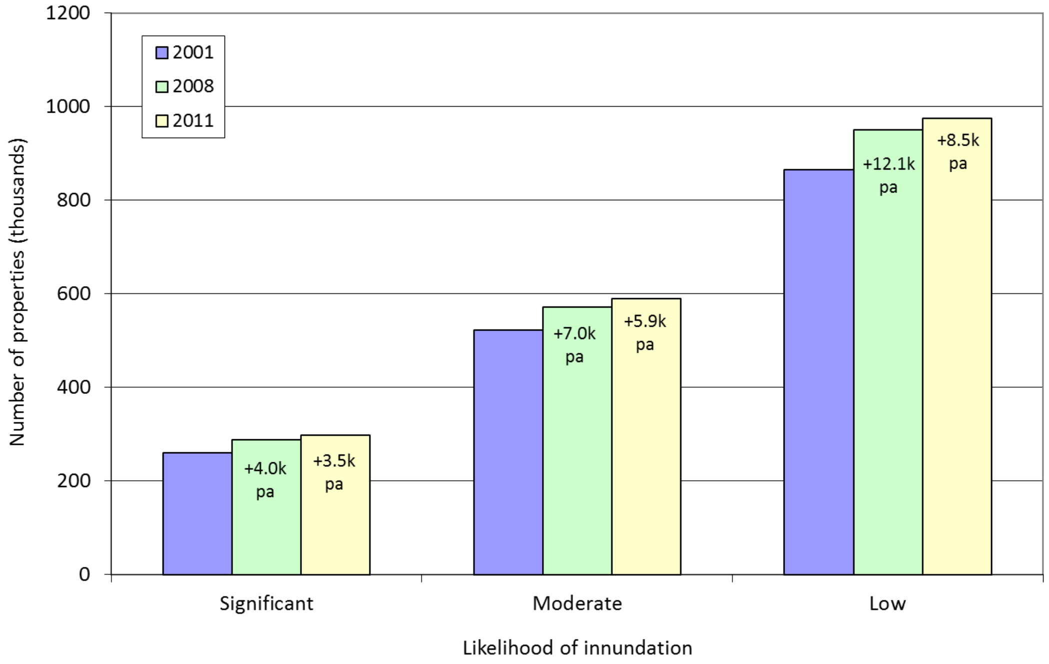

Figure 3.36: Number of residential properties in England by flood likelihood band

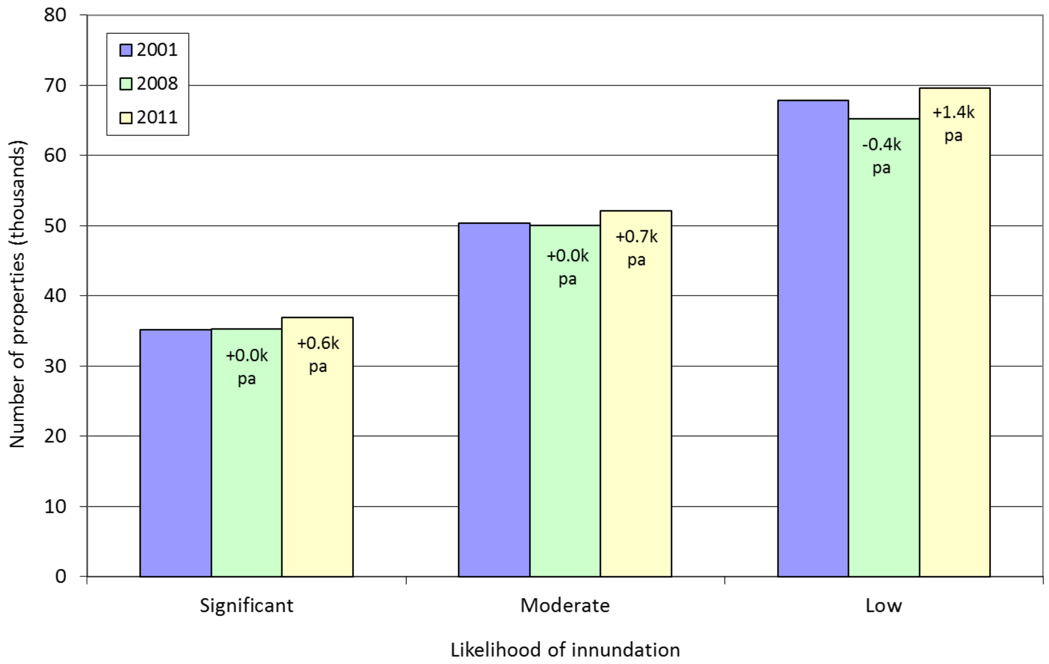

Figure 3.37: Number of non-residential properties in England by flood likelihood band

HR Wallingford (2012) also considered the variation in change in significant flood risk for different local authorities. These are shown in Figure 3.38 for both 2001-2008 and 2008-2011. From these two figures, it can be seen that in many cases, the number of residential properties and therefore people at significant risk of flooding has reduced both between 2001-2008 and 2008-2011. Between 2001 and 2008 there were 45 authorities (from a total of 326 local authorities in England) where there was a fall in the number of residential properties in areas of significant flood likelihood and another 11 where there was no change. Between 2008 and 2011 these numbers increased to 80 and 37 respectively, although HR Wallingford (2011) also noted that there was also an increase in the number of authorities locating 10% or more of the development within the significant flood likelihood areas (from 13 authorities between 2001 and 2008 to 31 between 2008 and 2011). Although this would suggest an increased risk to people in these cases, there may have been property or community level flood resilience and resistance measures used and also flood defence schemes may have been constructed for major housing developments which are not yet represented within the NaFRA data.

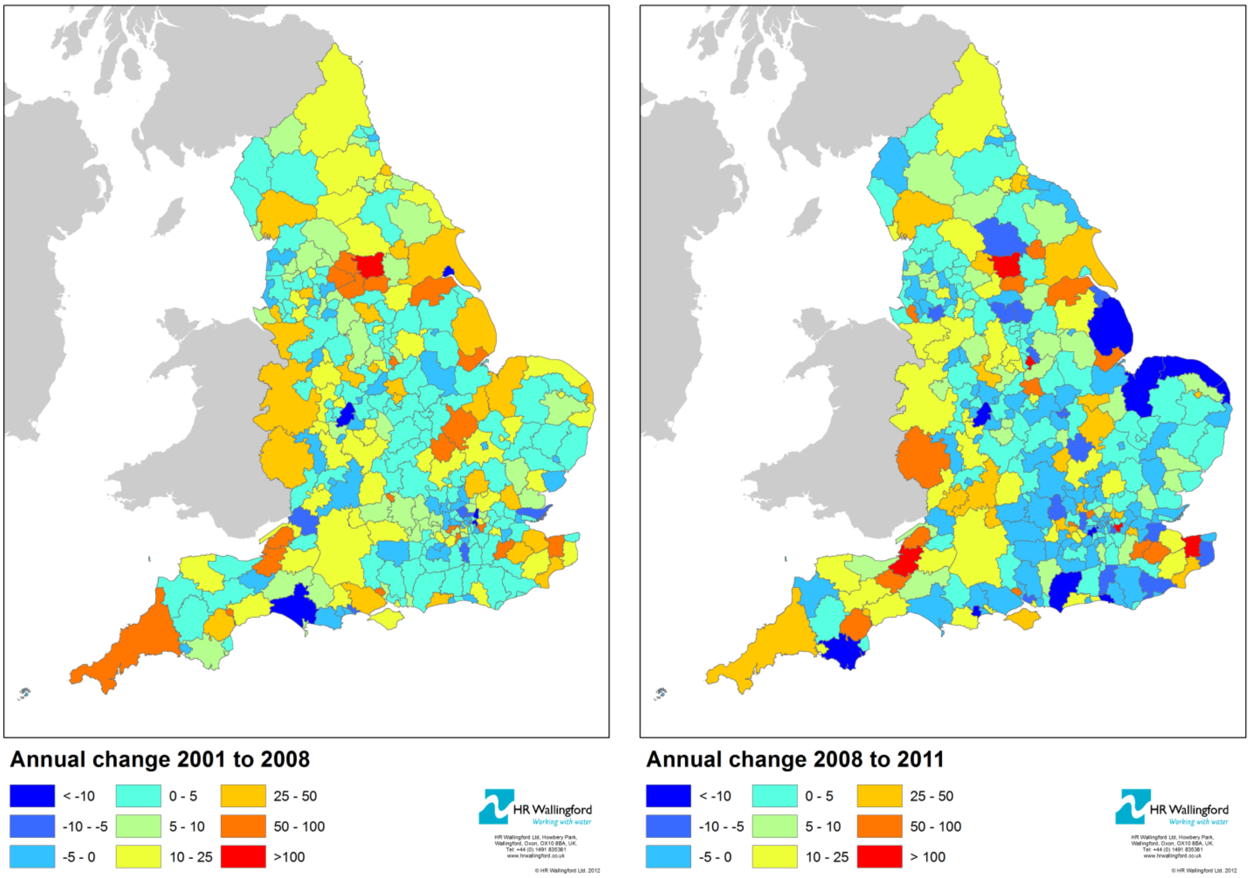

Figure 3.38: Annual change in the number of residential properties in areas at significant likelihood of flooding. 2001-2008 (left) and 2008-2011 (right) by local authority

3.14. Indicator 38: Number of flood incidents attended by the fire service

The fire statistics monitor, published each financial year by the Department for Communities and Local Government, analyses fire and rescue incident and fire casualty data for England based on records of all incidents attended by local authority and rescue services. Since 2009/10 this has included the number of flooding incidents attended by the fire service for each Fire and Rescue Service (FRS). Data is available up to 2012/13.

A summary of this data is given in Appendix C (Table C.1). This shows the number of flood incidents and total number of incidents as a proportion of all incidents attended by each FRS since 2009/10. These results are also shown graphically for two sample years in Figure 3.39.

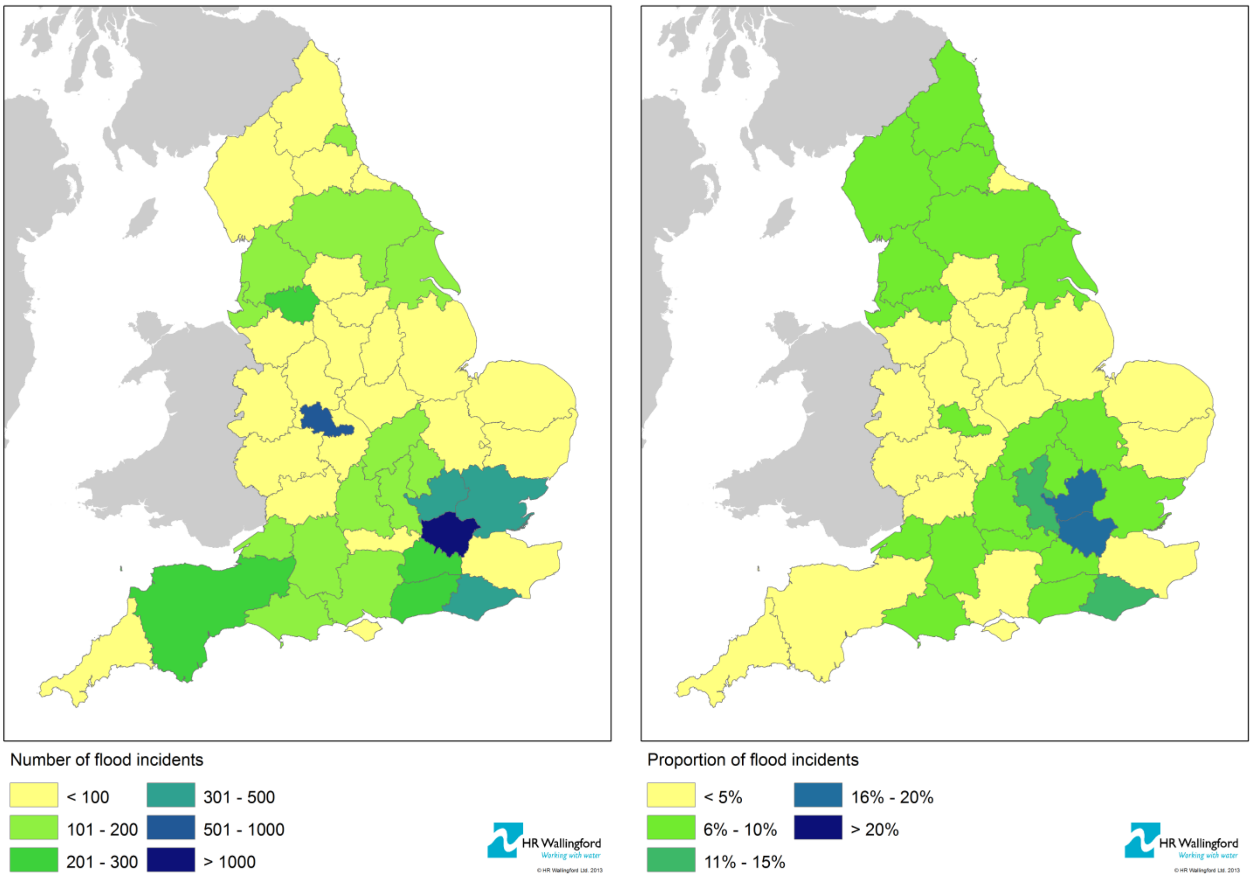

Figure 3.39: Number of flood incidents attended by each FRA (left) for 2010/11. Number of flooding incidents attended by each FRA as a proportion of the total incidents attended (right) for 2010/11

From these results, there are clear correlations across the FRA for the number of flood incidences attended each year. Between 2009/10 and 2010/11, 31 of the 46 FRS's show an increase in the number of flood incidences attended. This changes to 4 (or a decrease in 42 of the 46 FRAs) between 2010/11 and 2011/12 and 41 between 2011/12 and 2012/13. These results approximately correlate with the weather noted over these periods. Overall, significantly the least number of flood events attended by the FRAs over this four year period, 2011/12, corresponds to the drought of that year. Correspondingly, there was significant rainfall

the following year leading to extensive flooding across England. This corresponds to the year when overall most flood events were attended by the FRAs. Apart from 2010/11 to 2011/12, this pattern is not repeated for the total number of incidences attended by the FRAs.

For the number of flooding incidents attended by the FRAs, there is a relatively strong correlation to the population of the area. This is shown for 2010/11 on Figure 3.40, and indicates that in general, as the population increases, so does the number of flood incidences attended (these results are shown in tabular form for each FR authority in Table C.1, Appendix C). Noticeable outliers in these results are for Greater London, which had approximately three times as many flood incidents in this year relative to the average, and the West Midlands (clearly seen in the top right of Figure 3.40) and East Sussex, which had approximately twice this average. In contrast, there were few flood incidents relative to the population in Suffolk, South Yorkshire, Norfolk and Kent.

No correlation was noted against the area covered by each FRA. Correlation against flood risk areas or similar were not considered.

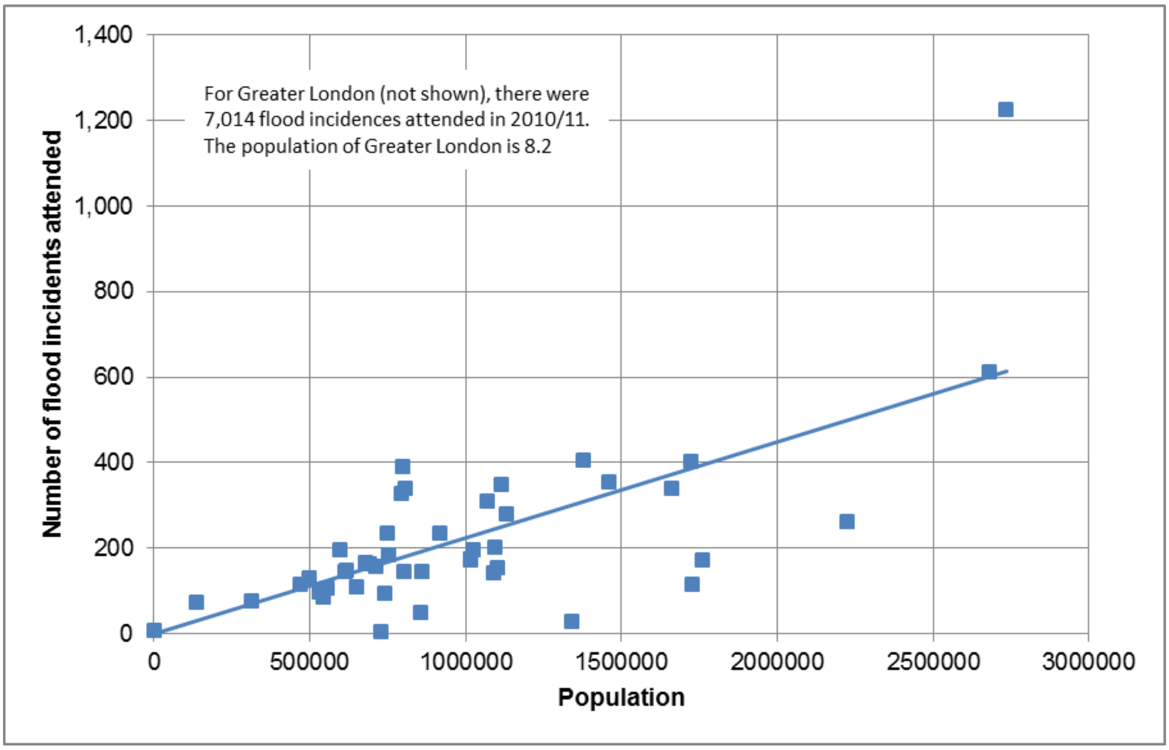

Figure 3.40: Number of flood incidents attended against population for each FR authority in England (Greater London is not shown)

3.15. Indicator 44: Number of households/people from lower socio-economic groups in areas at significant risk of flooding

Introduction

For the 2012 ASC progress report, HR Wallingford (2012) assessed the number of deprived households in flood risk areas, where deprived areas were defined as the highest 20% of ranked deprived areas based on the 2010 Index of Multiple Deprivation. This indicator was assessed using the same data sets and methodologies outlined for the number of properties/people at significant risk of flooding (see Section 3.13), although the analysis was only carried out for 2008 and 2011. The results for this analysis have therefore been replicated in this report, with no additional analysis carried out. A figure of 2.4 people per residential property has been used, as outlined in Appendix D.

Brief details of the methodology used are given in Section 2.2, with full details given in HR Wallingford (2012).

Results

The results of this assessment are shown in Table 3.13. This shows that the overall number of properties in the highest 20% of deprived areas that are within the floodplains has increased within all flood likelihood categories between 2008 and 2011. For the significant risk of flooding, this increase is from just over 53,000 properties to just over 55,000 properties, equivalent to approximately 128,000 and 132,000 people respectively. This equates to an increase of approximately 3.5%, or a relative increase of approximately 1.7% of all property/people in England.

Table 3.13: Number of residential properties in England in deprived areas at risk of flooding

Results expressed in thousands		Residential	
Year	**Type**	**count**	**%**
2008	Significant	53	0.2%
	Moderate	131	0.6%
	Low	266	1.2%
	Total property in England	22,266	100.0%
2011	Significant	55	0.2%
	Moderate	136	0.6%
	Low	274	1.2%
	Total property in England	22,679	100.0%

3.16. Indicator 46a: People living in fuel poverty

Public Health Outcomes Framework

In 2011 (HM Government, 2011), the Government outlined plans for a Public Health Outcomes Framework (PHOF) that would set out the broad range of opportunities to improve and protect health outcomes across the population, and to reduce inequalities in health. After a consultation process involving key stakeholders from local government, public health and the NHS, this was published in 2012. As it would take a number of years to provide information on the performance against the outcomes identified, a set of data indicators

were therefore developed that would enable trends to be established in specific areas of public health. First published in 2013, these data indicators are updated once per quarter and are typically based on publically available data sources.

People living in fuel poverty

One of the indicators developed as part of the PHOF was the number of people living in fuel poverty. The rationale for this indicator was that there is compelling evidence that the drivers of fuel poverty (low income, poor energy efficiency and energy prices) are strongly linked to living at low indoor temperatures (Wilkinson *et al.*, 2009), resulting in a range of avoidable health inequalities (Marmot Review). Based on a review of fuel poverty in 2012 (Hills, 2012), UK government therefore adopted a framework known as the Low Income High Costs (LIHC) measure for fuel poverty, where households are considered poor where:

- They have required fuel costs that are above average (the national median level).
- Were they to spend that amount, they would be left with a residual income below the official fuel poverty line.

The LIHC measure has therefore been adopted for the measure of the number of people living in fuel poverty. Based on data available from the Department of Energy and Climate, Figure 3.41 therefore shows the proportion of households living in fuel poverty in 2011[10], based on data at county and unitary authority level.

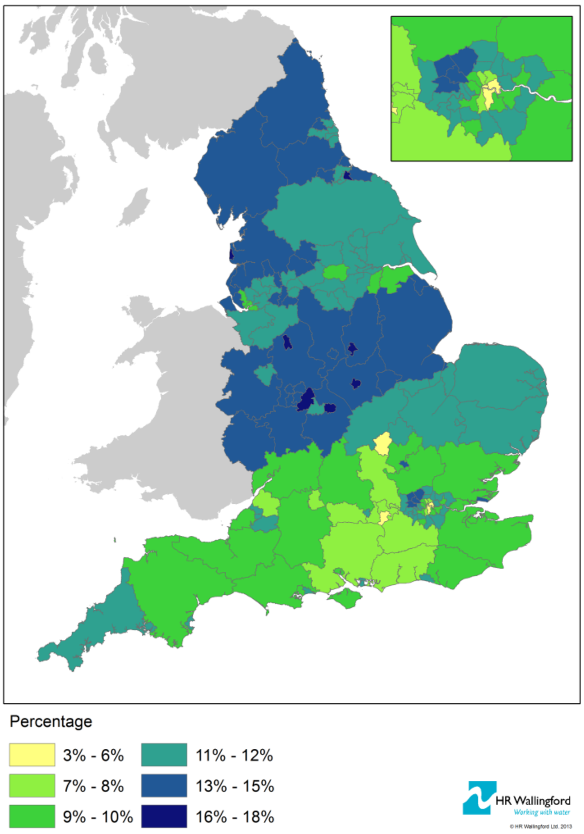

Figure 3.41: Percentage of households in fuel poverty for 2011 by county and unitary authority

[10] Only data for 2011 was available when compiling this report. This data is also only available for households, rather than people.

From Figure 3.41, there is a clear indication of a north-south divide. Considering an approximate line running from about the Severn Estuary to The Wash, at least 9%, but typically at least 11% of households averaged over county or unitary authority north of this line are in fuel poverty. South of this line, typically less than 10% of households are in fuel poverty, with several places, mainly central-southern England less than 8%. There are few southern locations where fuel poverty is noted to be comparable to northern locations. However, these are almost exclusively clustered in the Greater London area, as well as a few densely populated areas such as Bristol, Plymouth and Brighton and Hove. However, there are no southern locations where the proportion of properties in fuel poverty are greater than 13%.

The locations where fuel poverty is noted to be at its greatest are the unitary authorities of Blackpool and Leicester, the only two locations where the number of households in fuel poverty are greater than 16%. Typically, as for the southern locations, fuel poverty tends to be greater in the most densely populated areas.

3.17. Indicator 54: Concentrations of ground level Ozone

Introduction

Health effects of exposure to ground level ozone (O_3) are well established and are mainly associated with respiratory or cardiovascular illness (Bell *et al.* 2005, WHO 2004, DH 2006). At present, O_3 levels in the UK regularly exceed levels which have been identified as potentially harmful to health (Defra 2009). Elevated concentrations of ground-level ozone are produced during summer and spring photochemical smog episodes, caused by the interaction of nitrogen oxides and volatile organic compounds in the presence of sunlight. These can have detrimental effects on human health leading to an increase in respiratory hospital admissions and premature deaths (Pattenden *et al.*, 2010), as well as irritation to the eyes and nose. Very high levels can also cause damage to the airway lining.

O_3 is a secondary pollutant, not directly emitted; rather it is created and destroyed by chemical reactions with emitted precursor species. O_3 has been chosen as the most relevant air pollution indicator for this work, since O_3 concentrations are strongly related to climatic variables such as sunlight, temperature and wind speed. Nevertheless, O_3 concentrations are also strongly determined by precursor emissions rather than the climate alone (Heal *et al.* 2013).

Ozone is also an important greenhouse gas affecting the climate through direct radiative forcing as well as an indirect radiative forcing effect due to its impact on the productivity of natural vegetation by reducing the capacity of plants to take up CO_2 (Royal Society, 2008). Increased concentrations of ground-level O_3 could lead to significant reductions in regional plant production and crop yields, cause damage to ecosystems and deteriorate some building materials.

Methodology

Air quality monitoring networks exist at a number of locations around the UK, and are available from Defra's Air Quality data archive. Annual mean ozone concentrations (annual mean O_3), were obtained for representative sites within each government region, and were based on the mean of the daily maximum running 8 hour mean, as widely used in health effect studies.

Data was obtained from background monitoring stations[11] representing one rural and one urban site per region. The exception to this was for London, the North-east and the West Midlands, where no rural stations

[11] Background monitoring stations were chosen as they are not too heavily influenced by roadside emissions affecting O_3 concentrations through chemical reactions.

exist. O_3 levels are typically lower near busy streets in urban areas due to interaction between nitrogen oxides (NOx) mainly emitted from vehicles with ozone.

Results

The locations selected, with the range of data available is given in Table 3.14. The data for each of these locations is shown in Figure 3.42 and Figure 3.43.

Table 3.14: Monitoring stations where background Ozone levels have been assessed

Region	Station	Urban/Rural	Data range
South West (SW)	Plymouth Centre Yarner Wood	Urban Rural	1998-2013 (14) 1988-2013 (26)
South East (SE)	Southampton Centre Harwell	Urban Rural	1994-2013 (19) 1984-2013 (27)
London (LN)	London Bloomsbury	Urban	1992-2013 (22)
East of England (EE)	Southend-on-Sea Sibton	Urban Rural	2001-2013 (12) 1981-2013 (27)
West Midlands (WM)	Stoke-on-Trent Centre	Urban	1998-2013 (16)
East Midlands (EM)	Nottingham Centre Bottesford	Urban Rural	1997-2013 (17) 1982-2013 (31)
North West (NW)	Manchester Piccadilly Glazebury	Urban Rural	1996-2013 (18) 1989-2013 (21)
Yorkshire and Humberside (YH)	Leeds Centre High Muffles	Urban Rural	1993-2013 (21) 1988-2013 (25)
North East (NE)	Newcastle Centre	Urban	1992-2013 (19)

Note: Numbers in brackets after the data range indicate how many years of data are available.

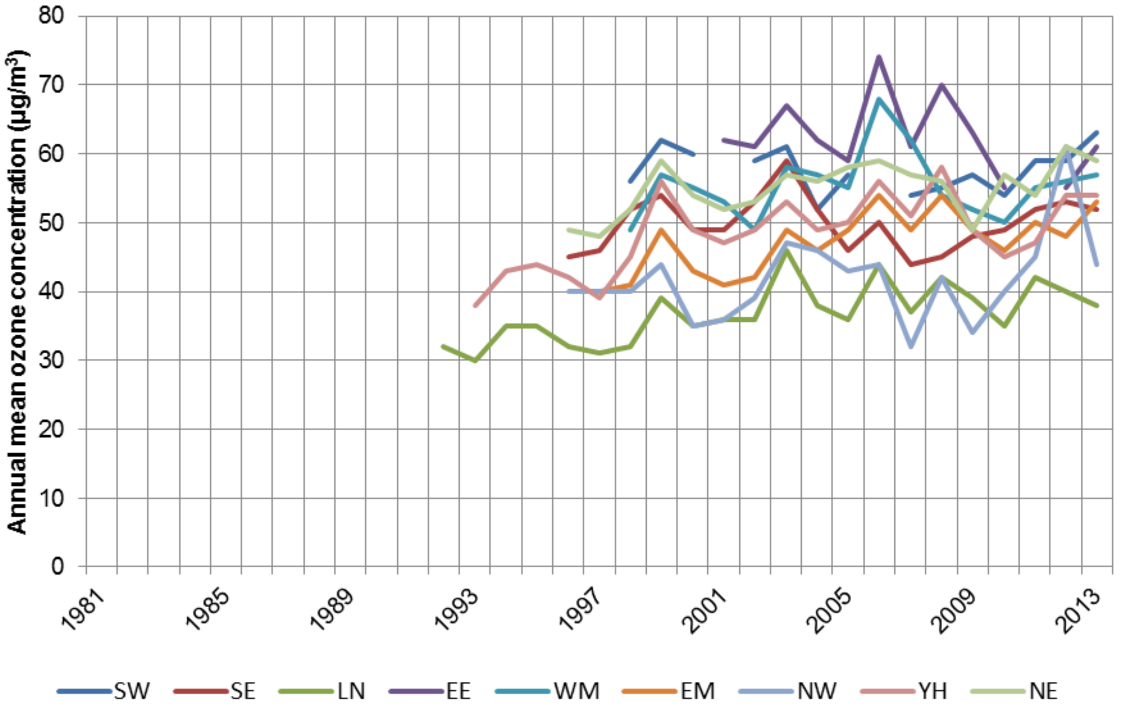

Figure 3.42: Annual mean of the daily maximum 8 hour ozone concentration at representative sites for each government region (urban sites)

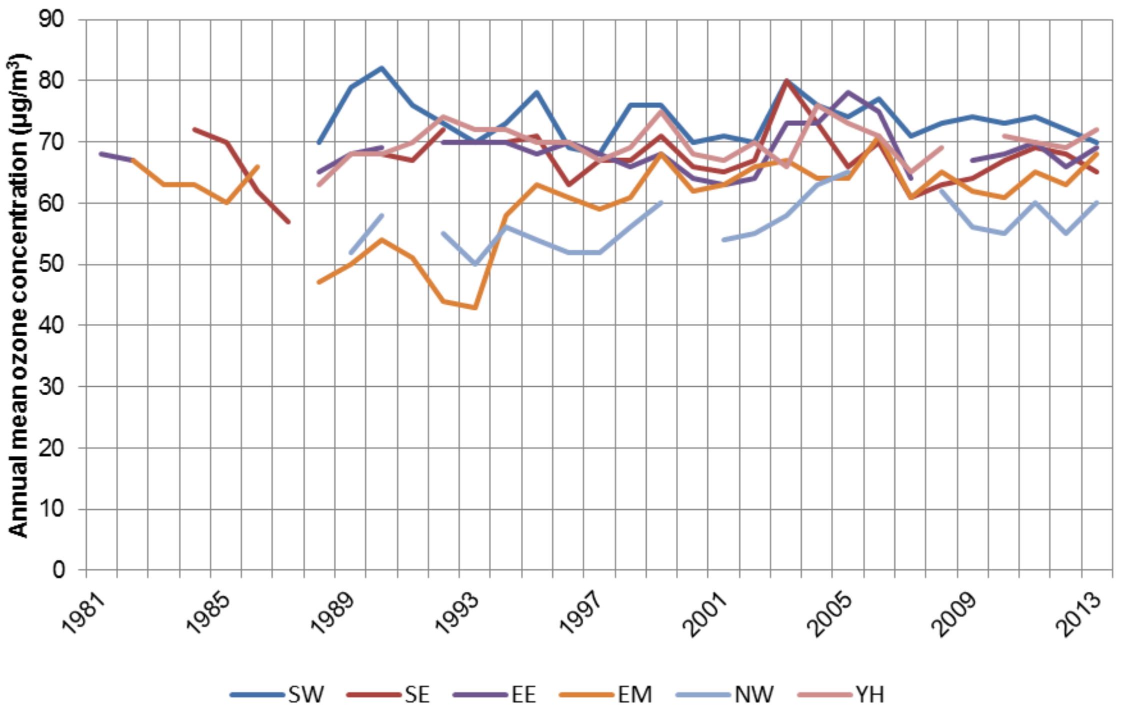

Figure 3.43: Annual mean of the daily maximum 8 hour ozone concentration at representative sites for each government region (rural sites)

From these results, a number of conclusions can be drawn:

- There is typically a positive trend in annual mean O_3 for most urban stations, of the order of 0.4-0.5µg/m^3 per year. Those stations that don't indicate any trend, or a negative trend (EE), show little correlation between years. This suggests that a positive trend of the order of 0.4-0.5 µg/m^3 in annual mean O_3 over the last 20 years could be inferred for urban locations. This is consistent with a decrease in NOx concentrations in urban areas (Vardoulakis *et al.*, 2011).
- Annual mean O_3 for rural areas is higher than urban areas. For the stations considered, this was typically of the order of 16-17 µg/m^3 (also see comment on comparative levels below). This is expected due to the higher levels of NOx in urban areas. The one exception to this is for the NW station in 2012, which appears to be an outlier.
- There is a clear correlation in recorded levels in annual mean O_3 across years, particularly for urban stations. This suggests that changes in O_3 on an annual basis are consistent countrywide for the same type of monitoring station.

The lowest levels of annual mean O_3 for urban background areas are observed in LN (average 36.8 µg/m^3), followed (approximately in order) by the NW, EM, YH, SE, WM, NE, SW and EE (average 62.5 µg/m^3). For rural areas, the lowest levels are observed in NW (average 56.6 µg/m^3), again followed in approximate order by EM, SE, EE, YH, SW (average 73.7 µg/m^3). However, the comments on trends should bear in mind that ground-level ozone concentrations depend on emission control policies on ozone precursor gases implemented at the international scale. This needs to be borne in mind if extrapolation of any trends is considered.

3.18. Indicator 56: Flowering season for different allergenic plants

Introduction

Pollen from wind pollinated plants is the most important cause of pollen related allergy in humans (Emberlin, 1997). Different allergenic plants produce different pollens at different times of the year, the time of release greatly dependant on temperature and vernalisation. Although there a large number of allergenic plants, there are certain plants in the UK that humans are most susceptible to, and these are given below.

- **Weeds**: Ambrosia (Ragweed), Dock, Mugwort, Nettle, Rape, Plantain
- **Trees**: Alder, Ash, Birch, Elm, Hazel, Lime, Oak, Pine, Plane, Poplar, Willow, Yew
- **Grasses**: there are at least 12 different species in the UK that produce pollen which cause allergies.

Methodology

To identify changes in the pollen season for different types of allergenic plants, records collected by Nature's Calendar[12] have been used to highlight two specific events in the life cycle of plants, namely budburst and first flowering[13]. Records are available over varying periods for alder, ash, hazel, oak (both pedunculate and

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[12] Nature's Calendar operated by The Woodland Trust is a phenology recorder network that based on recordings of certain events such as first flowering and budburst for plants, and first nest building and first mating for birds and animals can give an indication of the response of the natural world to climate change. With records originally collected by the Royal Meteorological Society from the end of the 19th century, since 2000, it has been opened up to the general public, and almost 50,000 across the UK now take part.

[13] Budburst is defined by Natures Calendar as the point when the colour of the new leaves is visible through openings in the swollen bud. First flowering is defined as when the petals have opened sufficiently to see inside the flower (see http://www.naturescalendar.org.uk/survey/events/ and more details).

sessile), as well as the silver birch species of the birch and timothy grass. Data available and timescales are given in Table 3.15 below.

Table 3.15: Data available for different allergenic plants

Species	Budburst	First Flowering
Alder[1,5]	1970 to 2013	1923 to 2005
Ash[6]	1991 to 2013	1932 to 2004
Hazel[2]	1999 to 2006	1922 to 2013
Oak (pedunculate)[3,7]	1977 to 2013	1933 to 2013
Oak (sessile)[8]	2002 to 2013	1952 to 2013
Silver Birch[4,9]	1975 to 2013	1948 to 2013
Timothy	-	1954 to 2013

Missing data (blocks greater than 3 years)

[1] No data for budburst for Alder over the period 1971 to 1975

[2] No data for budburst for Hazel over the period 2001 to 2005

[3] No data for budburst for Oak (pedunculate) over the period 1980 to 1988 and 1991 to 1994

[4] No data for budburst for Silver Birch over the period 1980 to 1986 and 1991 to 1994

[5] No data for first flowering for Alder over the period 1927 to 1930 and 1933 to 1942

[6] No data for first flowering for Ash over the period 1942 to 1945 and 1965 to 1971 and 1973 to 1995

[7] No data for first flowering for Oak (pedunculate) over the period 1954 to 1958 and 1960 to 1998

[8] No data for first flowering for Oak (sessile) over the period 1960 to 2002

[9] No data for first flowering for Silver Birch over the period 1950 to 1953

Results

Figure 3.44 to Figure 3.50 show the budburst and first flowering dates for each allergenic plant given in Table 3.15. Trend lines are drawn over the data range where it is considered that a noticeable trend is observed. However, due to the significant variability in the data sets, and the noticeable outliers in some cases (circled), no confidence lines have been drawn. Figure 3.51 collates the first flowering dates for all allergenic plants considered.

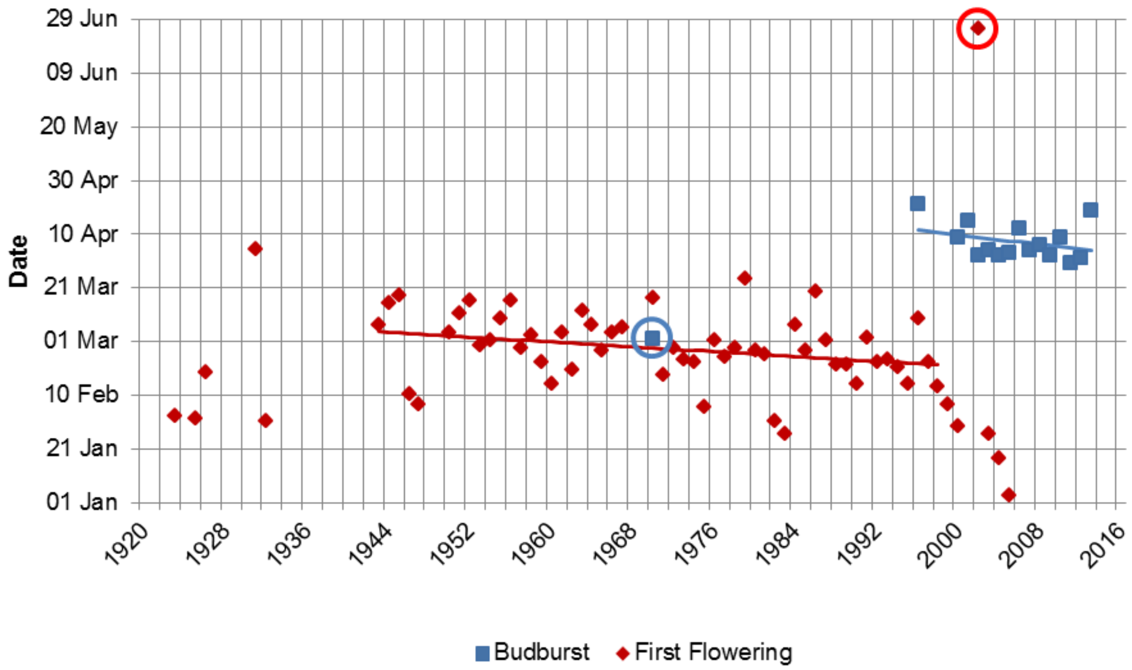

Figure 3.44: Budburst and first flowering dates for Alder (UK)

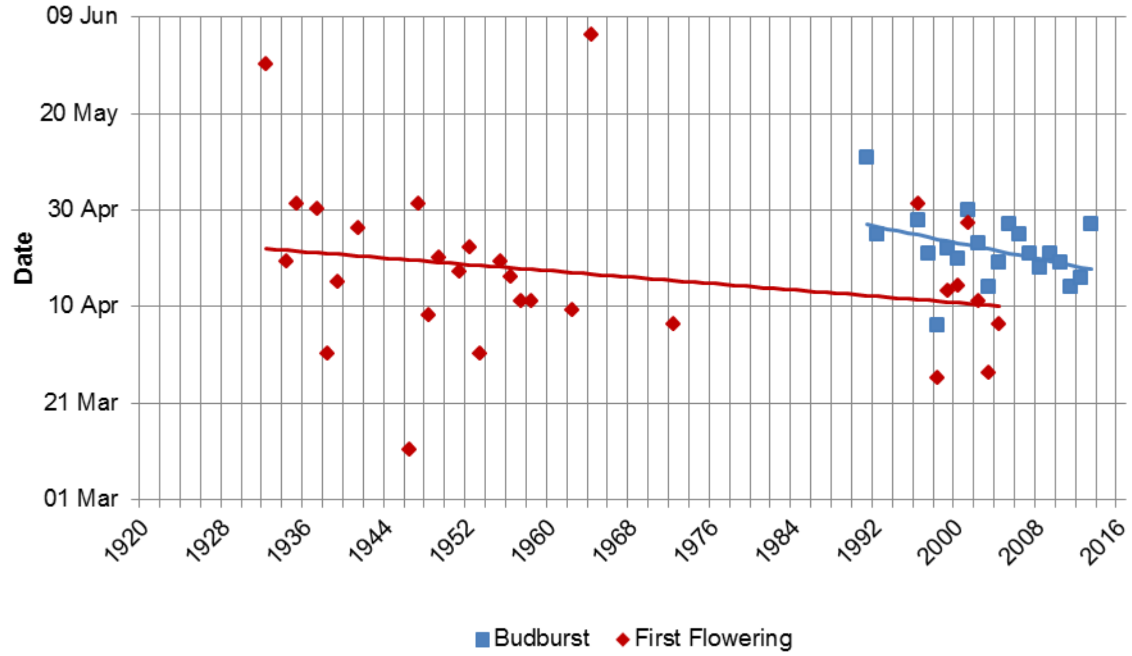

Figure 3.45: Budburst and first flowering dates for Ash (UK)

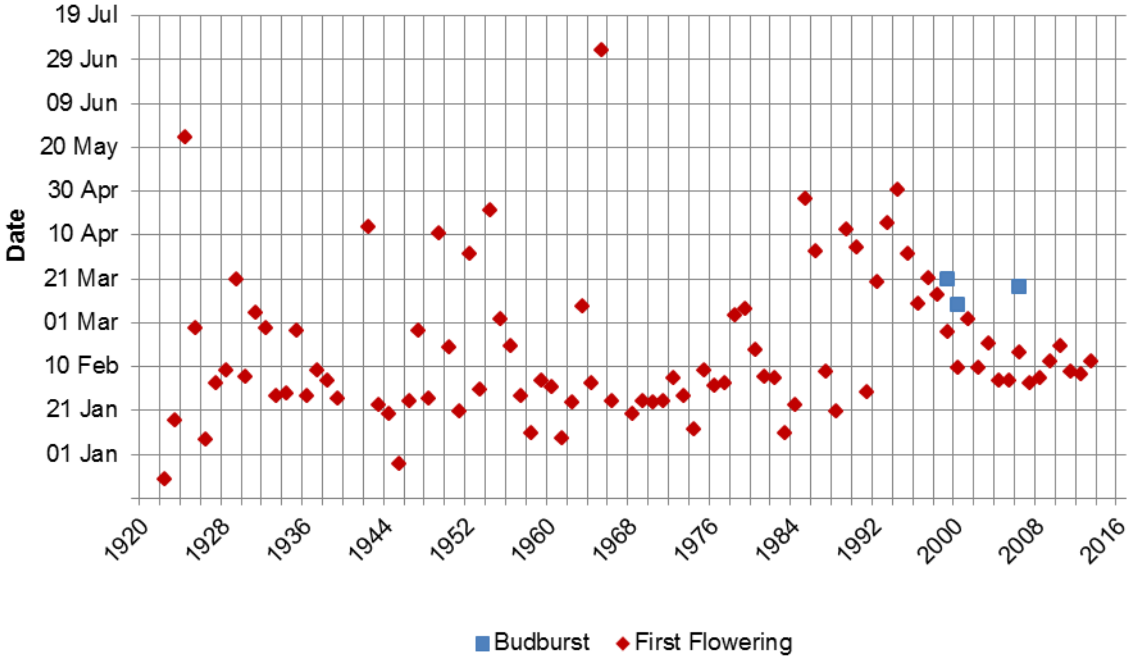

Figure 3.46: Budburst and first flowering dates for Hazel (UK)

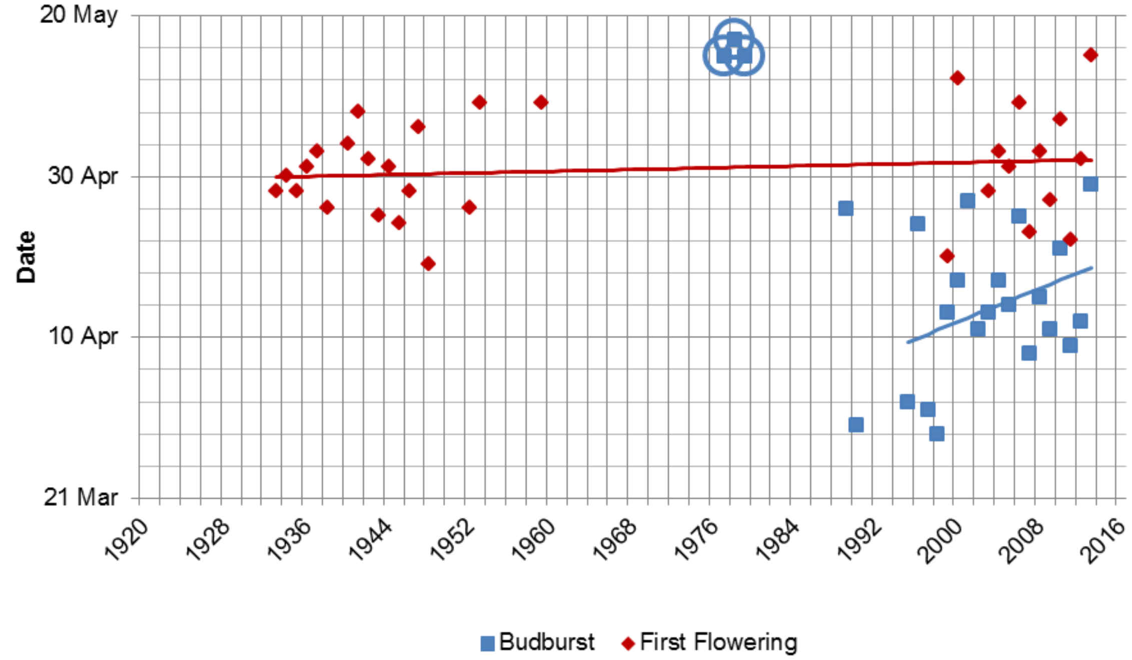

Figure 3.47: Budburst and first flowering dates for Oak (pedunculate) (UK)

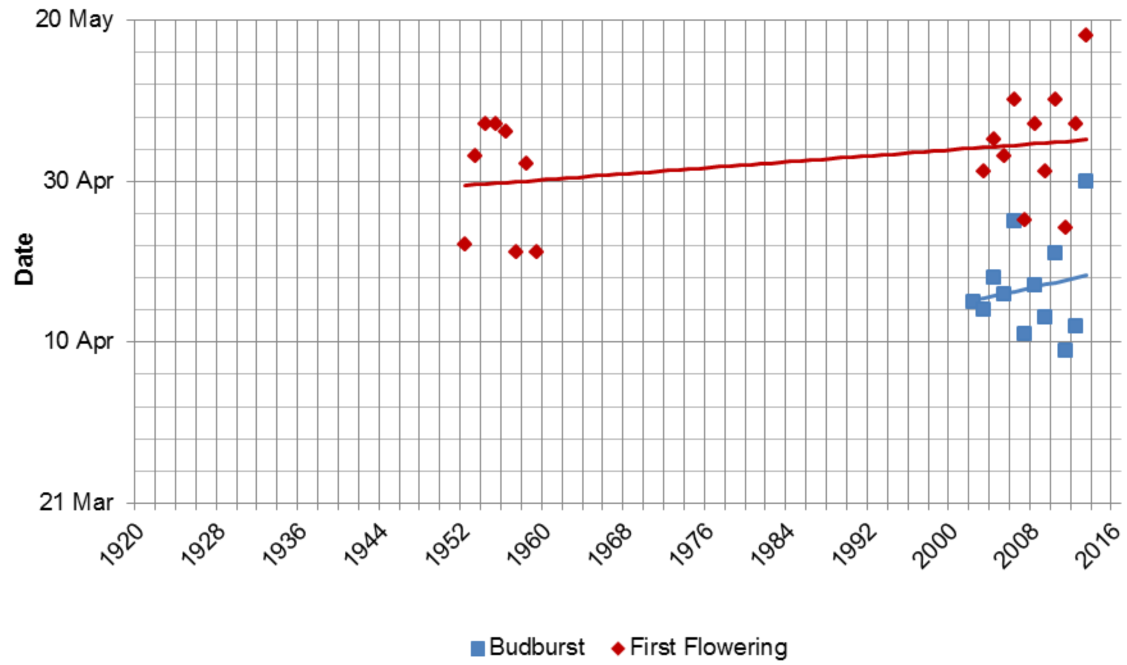

Figure 3.48: Budburst and first flowering dates for Oak (sessile) (UK)

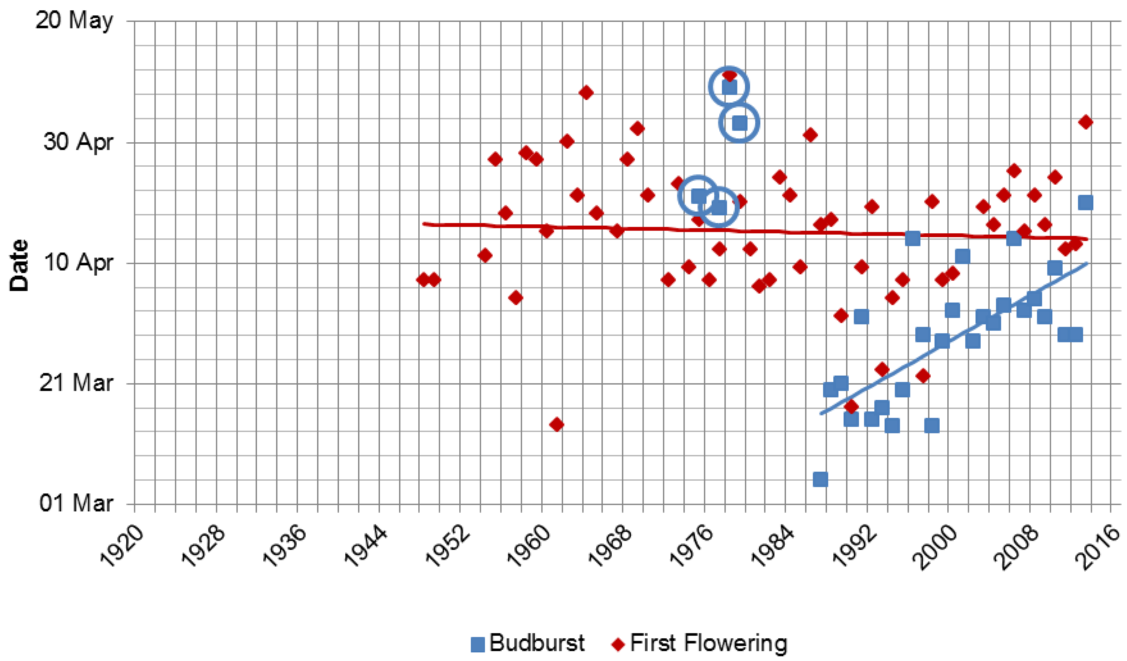

Figure 3.49: Budburst and first flowering dates for Silver Birch (UK)

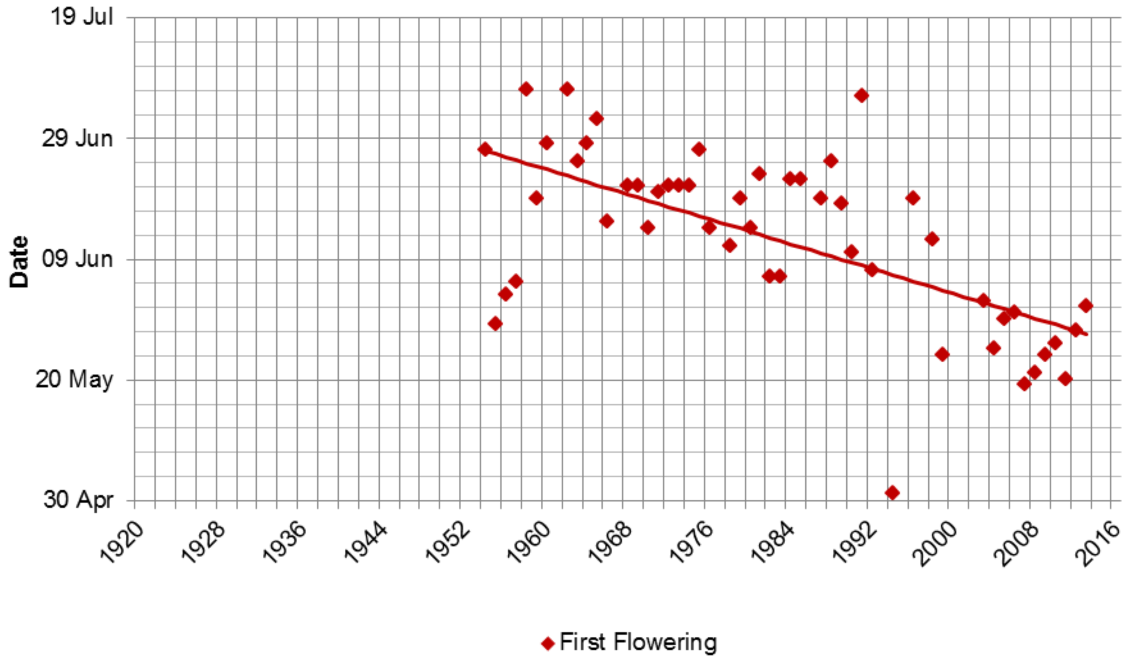

Figure 3.50: First flowering dates for Timothy Grass (UK)

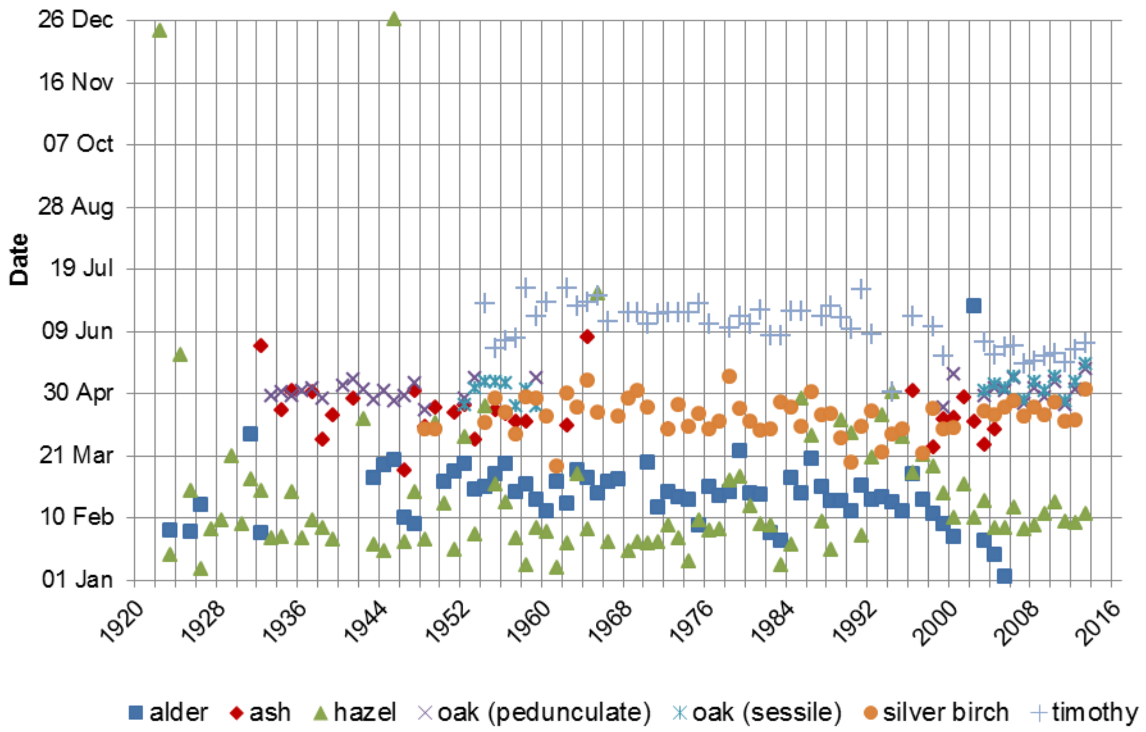

Figure 3.51: First flowering dates for each allergenic plant from Table 3.15 (UK)

From these figures, few strong conclusions can be drawn, particularly for budburst for which data is more limited, and there are noticeable outliers. As release of pollen is mainly linked to first flowering, conclusions have therefore only been made for first flowering.

- Conclusions:
  - First flowering for alder and ash appears to be occurring about 2-3 days per decade earlier;
  - Since the start of the current century, first flowering for alder has typically occurred up to a month earlier than currents trends would suggest;
  - First flowering for Hazel is very erratic, however, the general trend suggests that it is occurring about 2 days per decade later;
  - First flowering for oak and silver birch show no noticeable trend, although data for oak in particular are limited;
  - There is some convergence of first flowering for alder and hazel, with hazel flowering later. First flowering for both these tree species now typically occur around the same time, although the recent trend for alder means that its first flowering has typically occurred before hazel in recent years;
  - There is a general divergence of first flowering for ash, oak and silver birch;
  - First flowering for timothy grass has shown a noticeable trend, typically occurring about 5 days a decade earlier. Since the end of the 2nd World War, first flowering of timothy grass was typically two months later than oak. It is now typically just a month later;
  - There are no noticeable outliers following harsh winters such as 1946/47, 1962/63, 2009/10 and 2010/11;
  - Although data is only available for one type of grass, it does (as noted above) indicate a noticeable trend for earlier first flowering;
  - No data was available on any allergenic weeds, so no conclusions can be made on weeds;
  - There is no noticeable convergence of first flowering, and no years when first flowering for different species noticeably converges:
    - Considering oak (pedunculate) and oak (sessile) as one species, at no time did the first flowering for two different combinations of species occur within a week of each other;
    - This also occurred on only three occasions within two weeks for three different combinations of species (1949, 1956 and 1999).
  - There was possibly a divergence of first flowering in the 1960s and 1970s; however, this was probably more a function of lack of data on oak and ash than any other reason.

3.19. Indicator 58a: Sea levels above the 1990-1999 empirical 1 year level

Introduction

Flooding at the coastline, particularly at estuary locations is strongly correlated to high sea levels. This has been demonstrated recently with significant flooding on the east coast of England and north coast of Wales on 5/6 December 2013, and on the west coast of England on 3 January 2014 (as well as a number of significant flood events on the west and south coast through late January and early February 2014). Both these events occurred on the highest recorded sea levels for a number of years at most locations. These, as already noted, were two of several periods during the autumn/winter period of 2013/2014 when strong and sustained wind periods occurred, resulting in large surges on a large spring tide resulted in significant coastal flooding.

The number of times when the sea levels are above a certain extreme level is therefore a good indicator for risk of coastal flooding, particularly as other suitable data sets do not exist. As flooding generally only occurs during extreme sea levels, the certain level chosen was the empirical 1-year level based on sea levels recorded over the 10 year period between 1990 and 1999.

Methodology

To assess this indicator, recorded sea level data since 1990 was obtained from the National Tide and Sea Level Facility. This was done for all locations in England which is part of the UK National Tide Gauge Network where data was available. The starting date of 1990 was chosen as many tide gauges records only exist since the late 1980s/early 1990s. To increase the range of data, these gauges were then combined into five groups based on the levels of correlation observed between them. These groups are shown in Table 3.16.

Table 3.16: Grouping of English ports for assessment of mean exceedance of empirical 1-year level

Location	Ports
East coast	Cromer, Dover, Felixstowe, Immingham, Lowestoft, North Shields, Whitby
West coast	Avonmouth, Hinkley Point, Ilfracombe, Liverpool, Workington
South coast	Bournemouth, Devonport, Weymouth
South-East coast	Newhaven, Portsmouth
South-West coast	Newlyn

Results

Considering the amount of data available, Figure 3.52 shows the mean exceedance of the empirical 1 year level for each location around the English coastline[14].

[14] It should be noted that the results in Figure 3.52 are based on averaged results across all ports for each location, factored to account for the data available each year at each port. Therefore for example, in 1993, the 1 year level was exceeded twice at Newhaven with 100% of data available, yet only once at Portsmouth with 95% of data available. This gives an average number of exceedances of the 1-year level on the South-East coast of England of 1.54 times in 1993.

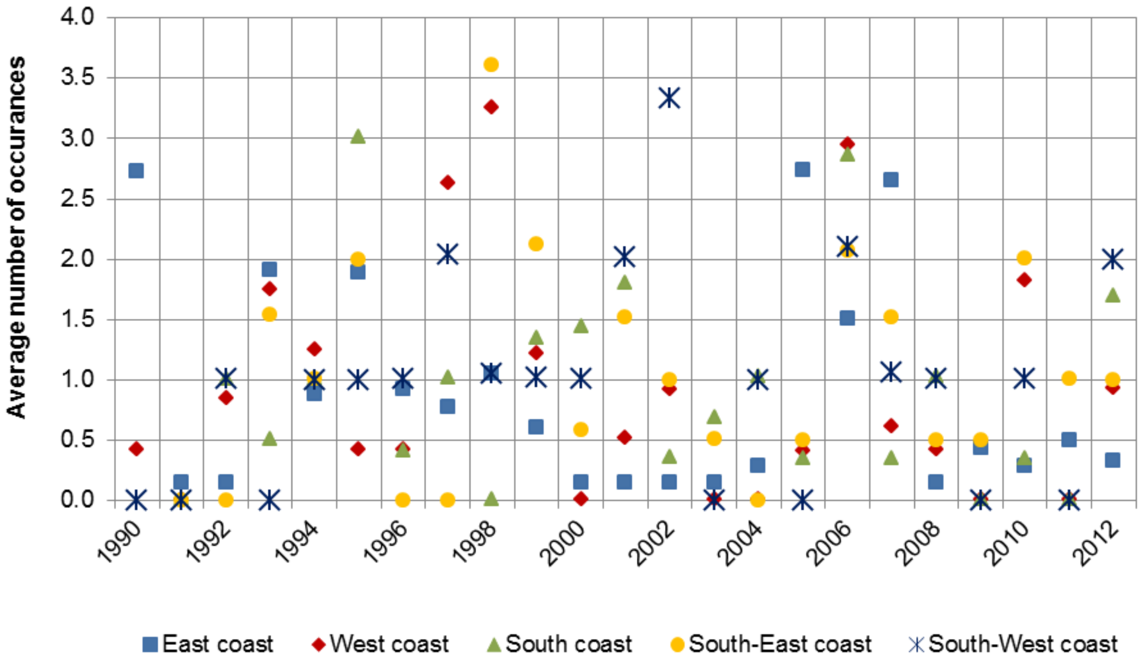

Figure 3.52: Number of times the 1990-1999 empirical 1 year sea level is exceeded for different English locations around the coastline

No firm conclusions can be drawn from Figure 3.52, as over such a short time period, the mean exceedance of the empirical 1 year sea level appears to be dominated by several long-term tidal cycles, particularly the 18.6 year lunar tidal cycle. It should be noted that in the absence of surge, the greatest tidal ranges (coinciding with highest astronomical tides and lowest astronomical tides) occur on a 4.5 yearly cycle when the four major tidal constituents are in phase. A trend with this phase is not observed within the short record assessed. Accounting for records from other tide gauges may remove some of the scatter from these results, but few reliable and easy to read records are available. However, in the future, with anticipated changes in mean sea levels, it is likely that some trends may be observed for some locations.

3.20.Indicator 59: Levels of indoor dampness/mould

Introduction

People living in damp or mouldy buildings are at increased risk of respiratory symptoms, respiratory infections and exacerbation of asthma. Exposure to mould and other dampness-related microbial agents also increases the risks of rare conditions, such as hypersensitivity pneumonitis, allergic alveolitis, chronic rhinosinusitis and allergic fungal sinusitis.

If left untreated, damp conditions and mould growth in the home can exacerbate these effects, and can also have a negative impact on the fabric of the dwelling, leading to its rapid deterioration.

Methodology

As part of the English Housing Survey (see Section 3.7) based on survey data, the percentage of homes and tenures with different categories of damp have been estimated continually since 2003, with some data prior to this year. Damp and mould have been defined for three main categories which are:

- **Rising damp**: this is when water from the ground rises up into the walls or floors because damp proof courses in walls or damp proof membranes in floors are either not present or faulty. It is defined as being present if it exists in at least one room.
- **Penetrating damp**: this is as a result of leaks from faulty components of the external fabric e.g. roof covering, gutters etc., or leaks from internal plumbing e.g. water pipes, radiators etc. It is defined as being present if it exists in at least one room.
- **Condensation or mould**: this is caused by water vapour generated by activities like cooking and bathing condensing on cold surfaces like windows and walls. As virtually all homes have some level of condensation occurring, homes are only considered where there are patches of mould growth on walls and ceilings and/or mildew on soft furnishings.

Results

Figure 3.53 and Figure 3.54 show the results of these surveys for the different types of damp, and for different types of tenure respectively.

From these results, there appears to be a general fall in the number of properties with the different types of damp (Figure 3.53). This is particularly the case for the last two years (2010 and 2011) where, for example, the percentage of houses with any damp problem has fallen by about 1.5-2.0% of all houses per year. Relatively speaking, the proportion of houses with damp have decreased by about 2-3% per year, although over the period 2010 and 2011, this has increased significantly to about 10 times this rate.

These general patterns are repeated for the different tenure types, including similar patterns for 2010 (Figure 3.54). Although data is not available for 2011, the significantly increased rate for 2011 would be repeated for all tenures, and is likely to be a similar rate for the different tenure types.

The reasons for these significant reductions in damp problems for 2010 and 2011 and whether this trend is likely to continue are not known.

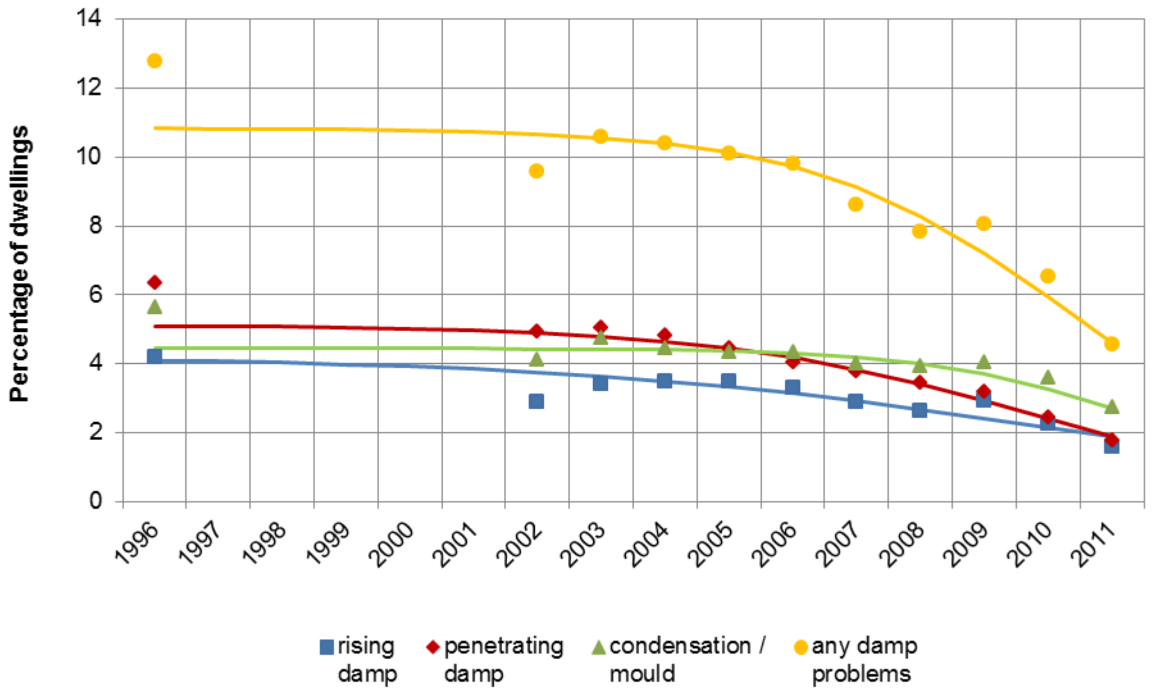

Figure 3.53: Dwellings in England with damp problems in one or more rooms, 1996-2011

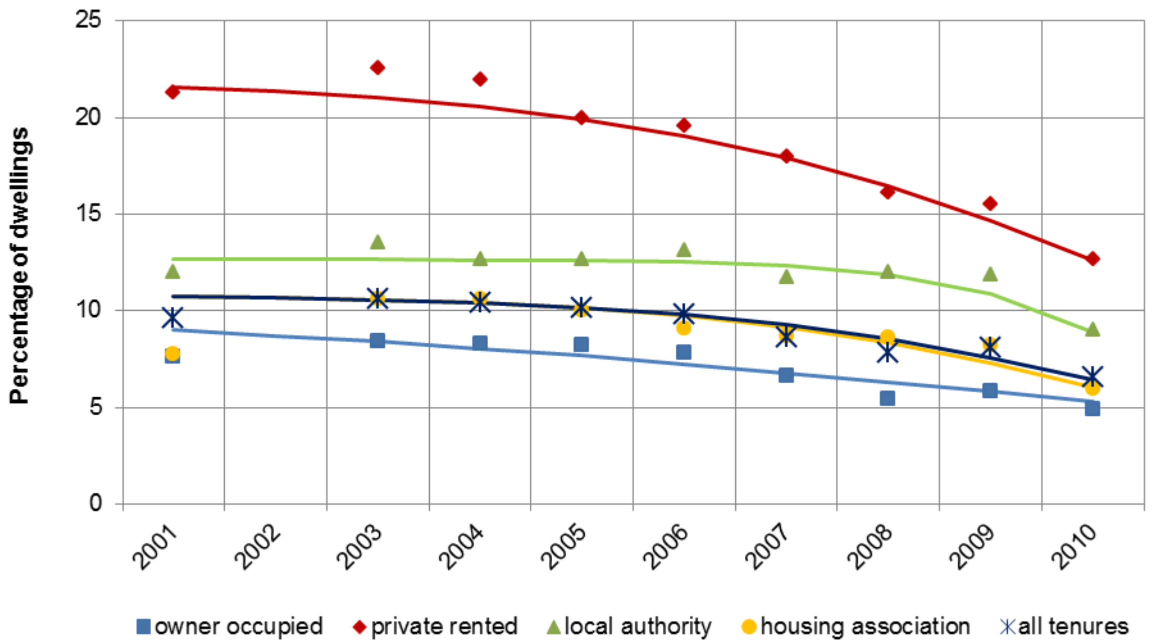

Figure 3.54: Any type of damp problem in England by tenure

3.21.Indicator 63: Average time population spends outdoors

Introduction

In the UK it has been estimated that we spend around 90% of our time indoors, Capon and Oakley (2012). Being outdoors can have a number of positive and negative health implications. For example, there is likely to be increased exposure to adverse weather conditions, air pollution, traffic and noise for populations outdoors. However, there are clearly public health benefits in exercising and utilising outdoor space for recreation in terms of improved general health and fitness.

Methodology

The percentage utilisation of outdoor space for exercise/health reasons by city/town is one of the indicators developed as part of the Public Health Outcomes Framework (see Section 3.16), and is available for two years, namely 2011/12 and 2012/13. It is defined as the number of people who have visited the natural environment for health or exercise reasons in the previous seven days, and does not take account of duration of that visit. Although this indicator is not a reliable indicator for the average period of time a population spends outdoors, it does give some indication of regions where people spend more time outdoors, particularly in relation to positive health outcomes (exercise, wellbeing etc.).

Results

Figure 3.55 shows the number of people who have visited the natural environment for health or exercise reasons in the previous seven days by counties and unitary authorities. This generally indicates that individuals in the west and south of the country spend more time outside than locations further north and east, which might reflect the warmer weather in these regions (see Section 3.1). There are some exceptions to this, most notably London and the south-east which may reflect the proportion of individuals in urban areas (see Figure 3.15), where access to the natural environment is more difficult and limited.

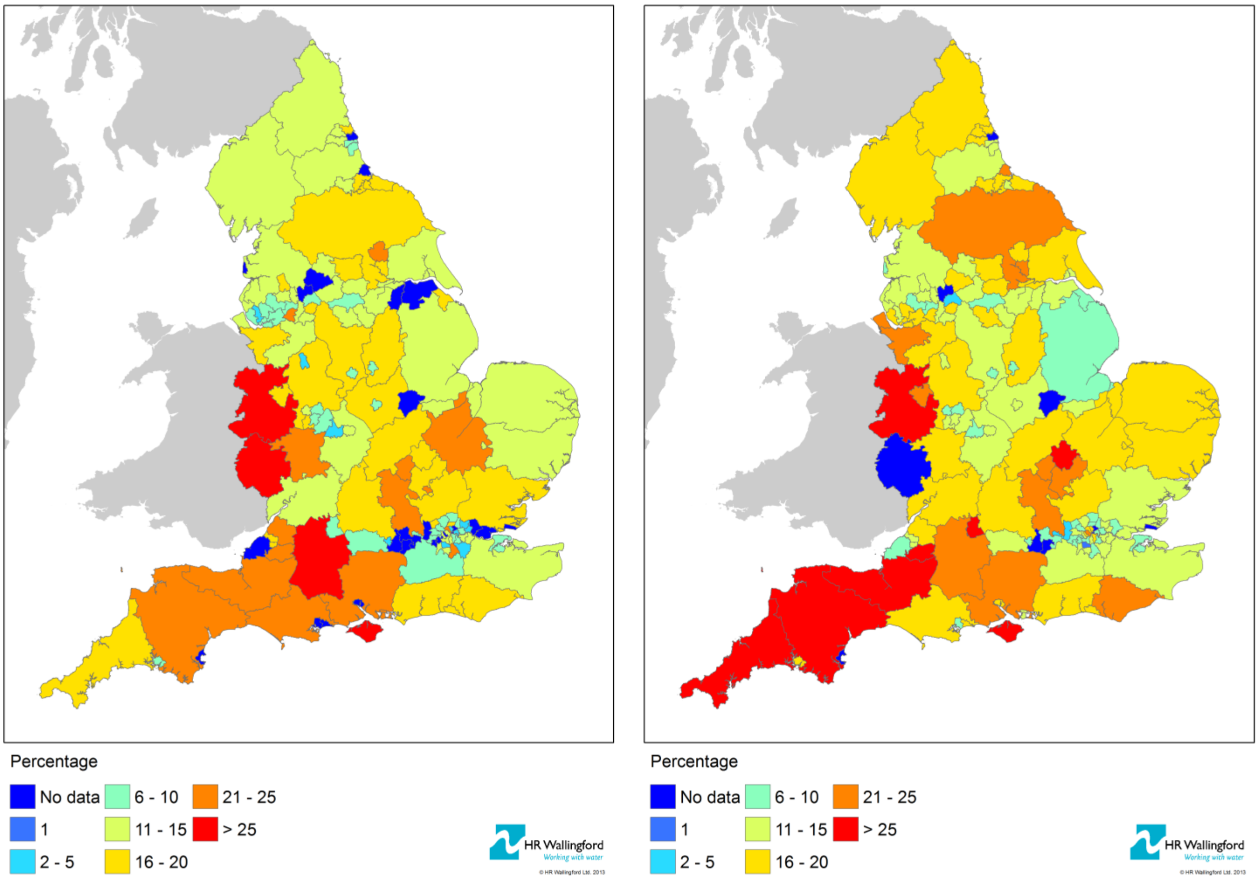

Figure 3.55: Percentage of people who have visited the natural environment for health or exercise reasons in the previous seven days (2011/12 left, 2012/13 right) by county and unitary authority

3.22.Indicator 71: UVR Exposure

Introduction

In 1988, the former National Radiological Protection Board (NRPB - now part of PHE CRCE) set up three monitoring stations to continuously measure terrestrial solar radiation at different latitudes within GB. These were at NRPB sites at Chilton, Oxfordshire, at latitude of approximately 52°N; Leeds (at about 54°N) and Glasgow (at about 56°N). This network was extended, in cooperation with the UK Met Office, to three sites at Met Office observatories at Camborne (since 1993, about 50°N), Lerwick (since 1993, about 60°N) and Kinloss (since 1995, about 58°N).

Figure 3.56 shows the yearly variation of total erythemal radiant exposure for the six monitoring locations in the UK. Erythemal radiant exposure (or erythemal dose) is an effective dose, where the spectral radiant exposure is spectrally weighted with the erythema spectral weighting function. The weighting function takes account of the difference in sensitivity of the skin to ultraviolet radiation at different wavelengths: UV-B is more effective at producing erythema than UV-A.

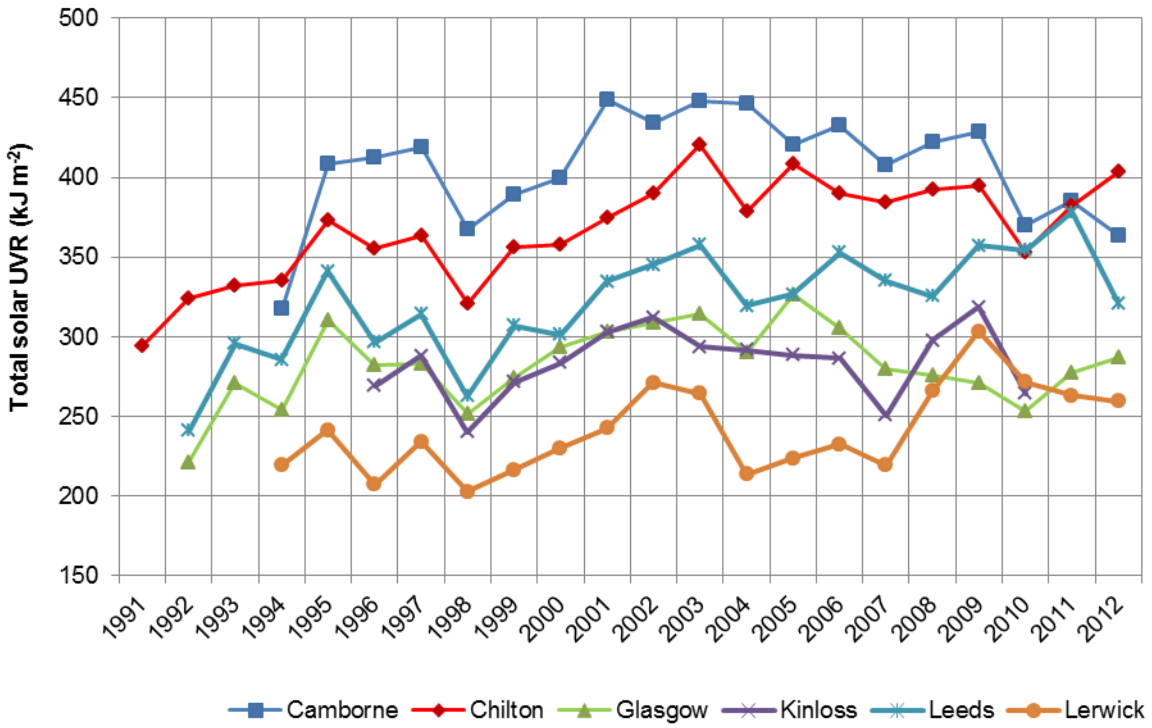

Figure 3.56: Total solar UVR (erythemal dose) per year for selected sites around the UK

Camborne in Cornwall is where the highest and Lerwick in the Shetland Islands is where the lowest H_{er} were measured throughout the year. Generally, the H_{er} level at a high-latitude is relatively low; this will be due to the lower solar elevation relative to the more southerly sites. The remainder of the sites in descending order in terms of H_{er} exposure from south to north were Chilton, Leeds, Glasgow and Kinloss (see Figure 3.56). The long-term trend behaviour of erythemally radiant exposure for these sites was assessed previously by using the data for the period up to 2008 and results were presented (O'Hagan *et al*. 2012; Hunter *et al.*, 2011).

3.23. Infrastructure Indicators

In parallel with the 'health' theme work, a sister project is taking place for indicators to assess the resilience of infrastructure in England to the projected impacts of climate change. Within that theme there are indicators that will be of interest to the reader of this report, in particular, exposure and criticality of hospitals, care homes, GPs, schools, emergency services, clean water and waste water infrastructure, energy infrastructure and transport infrastructure to hazards including flooding from groundwater, coasts, rivers and surface water, subsidence and landslides.

The results of the infrastructure indicators are presented in the sister report, HR Wallingford (2014).

4. References

Alcock I., White M.P., Wheeler B.W., Fleming L.E. and Depledge M.H. 2014. Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas. Environ. Sci. Technol., **48** (2), pp 1247–1255.

Amson D. 2012. The Effect of Trees and Grass on the Thermal and Hydrological Performance of an Urban Area. PhD. Thesis. University of Manchester.

Bell M.L., Dominici F. and Samet J.M., 2005: A meta-analysis of time-series studies of ozone and mortality with comparison to the National Morbidity, Mortality, and Air Pollution Study. Epidemiology, **16**, 436-445.

Capon R. and Oakley G. 2012. Climate Change Risk Assessment for the Built Environment Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Coley D. and Kershaw T. 2010. Changes in internal temperatures within the built environment as a response to a changing climate. Building and Environment, **45**(1): 89-93.

Defra. 2009. Department for Environment, Food and Rural Affairs, The Scottish Executive, Welsh Assembly Government and the Department of the Environment for Northern Ireland. Ozone in the United Kingdom. Air Quality Expert Group.

Department for Communities and Local Government (DCLG). 2012. Investigation into overheating in homes: Literature review. Report by AECOM, July 2012.

Department of Health. 2006. Committee on the Medical Effects of Air Pollutants. Air Pollution and Cardiovascular Disease. Department of Health, London.

Emberlin J., Smith M., Close R. and Adams-Groom B. 2007. Changes in the pollen seasons of the early flowering trees *Alnus spp.* and *Corylus spp.* in Worcester United Kingdom 1996-2005. International Journal of Biometeorology **51**, 181-191.

Hajat S., Kovats R.S. and Lachowycz K. 2007. Heat-related and cold-related deaths in England and Wales: Who is at risk? Occupational and Environmental Medicine. **64**(2): 93-100.

Hajat S., Vardoulakis S., Heaviside C. and Eggen B. 2012. Temperature effects of climate change on human health. In: Health effects of climate change in the UK 2012 – Current evidence, recommendations and research gaps. Vardoulakis S. and Heaviside C. (Eds). Health Protection Agency.

Hajat S, Vardoulakis S, Heaviside C, Eggen B. 2014. Climate change effects on human health: projections of temperature-related mortality for the UK during the 2020s, 2050s, and 2080s. J Epidemiol Community Health. Published Online First: [4th February 2014] doi:10.1136/jech-2013-202449.

Hames D. and Vardoulakis S. 2012. Climate Change Risk Assessment for the Health Sector. UK 2012 Climate Change Risk Assessment, Defra, London.

Heal M.R., Heaviside C., Doherty R.M. Vieno M., Stevenson D.S. and Vardoulakis S. 2013. Health burdens of surface ozone in the UK for a range of future scenarios. Environment International. **61**, 36-44.

Hills J. 2012. Getting the measure of fuel poverty. Final report of the fuel poverty review.

HM Government. 2011. Healthy lives, healthy people: update and way forward. July 2011.

HR Wallingford. 2012. Development of spatial indicators to monitor changes in exposure and vulnerability to flooding and the uptake of adaptation actions to manage flood risk in England: Results 2012. Report EX6739, release 2.0, July 2012.

HR Wallingford. 2012. Development of spatial indicators to monitor changes in exposure and vulnerability to flooding and the uptake of adaptation actions to manage flood risk in England: Technical Note 2012. Report TN-MCS0743-01, release 2.0, July 2012.

HR Wallingford, 2014. Indicators to assess the resilience of infrastructure in England to the projected impacts of climate change, RT003.

Hunter N., Pearson A.J., Campbell J.I., and Dean S.F. 2011. Solar ultraviolet radiation in Great Britain (1989-2008). Chilton, HPA-CRCE-020.

Jenkins G.J., Perry M.C. and Prior M.J. 2008. The climate of the United Kingdom and recent trends. Met Office Hadley Centre, Exeter, UK.

Jones P.D., Lister D.H. and Li Q. 2008. Urbanization effects in large-scale temperature records, with an emphasis on China. J. Geophys. Res. 113, D16122.

Jones P.D. and Lister D.H. 2009. The Urban Heat Island in Central London and urban-related warming trends in Central London since 1900. Weather 64. (12). pp. 323-327.

Marmot Review. 2010. “Fair Society, Healthy Lives”.

NEGTAP. 2001. Transboundary air pollution: Acidification, eutrophication and ground-level ozone in the UK. Prepared by the National Expert Group on Transboundary Air Pollution (NEGTAP) on behalf of the Department for Environment, Food and Rural Affairs, the Scottish Executive, Welsh Assembly Government and the Department of the Environment in Northern Ireland.

Macrory I. 2012. Measuring national well-being; households and families, 2012. Office for National Statistics.

O’Hagan J., Hunter N. and Eggen B. 2012. Climate change, ultraviolet radiation and health. In: Health effects of climate change in the UK 2012 – Current evidence, recommendations and research gaps. Vardoulakis S. and Heaviside C. (Eds). Health Protection Agency.

Oke T.R. 1982. The energetic basis of the urban heat island. Quarterly Journal of the Royal Meteorological Society 108 (455): 1–24.

Osborn T.J. and Hulme M. 2002. Evidence for trends in heavy rainfall events over the United Kingdom. Philosophical Transactions of the Royal Society London series A 360, 1313-1325.

Pathan A., Young A. and Oreszczyn T. 2008. UK Domestic Air Conditioning: A study of occupant use and energy efficiency. Air Conditioning and the low carbon cooling challenge. Windsor, UK, Network for Comfort and Energy Use in Buildings (NCEUB).

Pattenden S., Armstrong B., Milojevic A., Heal M.R., Chalabi Z., Doherty R., Barratt B., Kovats R.S. and Wilkinson P. 2010. Ozone, heat and mortality: Acute effects in fifteen British conurbations. Occupational Environmental Medicine **67**, No. 10, pp 699-707. October 2010.

Perry M. and Hollis D. 2006. The generation of monthly gridded datasets for a range of climate variables over the United Kingdom. Version 2.0, 05/06/2006. The Met. Office.

Photochemical Oxidants Review Group (PORG). 1997. Ozone in the United Kingdom. Fourth report prepared by the Photochemical Oxidants Review Group for the (DETR) Department of the Environment, Transport and the Regions.

Public Health England/NHS England. 2013a. Heatwave plan for England 2013: Protecting health and reducing harm from severe heat and heatwaves. May 2013.

Public Health England/NHS England. 2013b. Cold weather plan for England 2013: Protecting health and reducing harm from cold weather. October 2013.

Royal Society. 2008. Ground-level ozone in the 21st century: Future trends, impacts and policy implications. Science report. Royal Society.

Vardoulakis S. and Heaviside C. [eds.] 2012. Health Effects of Climate Change in the UK 2012 – Current evidence, public health recommendations and research gaps. Health Protection Agency. Centre for Radiation, Chemical and Environmental Hazards, UK.

Vandentorren S., Bretin P., Zeghnoun A., Mandereau-Bruno L., Croisier A., Cochet C., Ribéron J., Siberan I., Declercq B. and Ledrans M. 2006. August 2003 heat wave in France: risk factors for death of elderly people living at home. European Journal of Public Health, Vol. 16, No. 6, 583–591.

Wilkinson P., Smith K.R., Davies M., Adair H., Armstrong B.G. Barrett M., Bruce N., Haines A. and Hamilton I. 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: household energy. The Lancet. Vol. 374. Issue 9705. 1917-1929.

WHO. 2004. Meta-analysis of time-series studies and panel studies of particulate matter (PM) and ozone (O_3), Eur/04/5042688. WHO Regional Office for Europe, Copenhagen.

Wilby R.L., Jones P.D. and Lister D.H. 2011. Decadal variations in the nocturnal heat island of London. Weather **66**(3): 59-64.

Young A.N., Pathan A. and Oreszczyn T. 2007. Domestic air conditioning – occupant use and operational efficiency, Final Report. The Bartlett School of Graduate Studies, University College London. London, UK.

Zero Carbon Hub. 2010. Carbon compliance for tomorrow's new homes: A review of the modelling tool and assumptions. Topic 3 - Future climate change. August 2010.

Appendices

A. Health and Emergency Planning expert meeting 13th November 2013

The preliminary list of indicators, methodology and data sources based on HR Wallingford 2013, were presented and discussed at an expert meeting at the ASC on 13th November 2013. The list of attendees at this meeting are given below:

Client

Kathryn Humphrey	ASC Project Manager
Daniel Johns	ASC
Dave Thompson	ASC
Alex Townsend	ASC

Project Team

Dominic Hames	HR Wallingford Project Manager
Alison Hopkin	HR Wallingford
Mike Panzeri	HR Wallingford
Eleanor Hall	HR Wallingford
Sotiris Vardoulakis	Public Health England
Clare Heaviside	Public Health England
John Thornes	Public Health England

Consultees

John Battersby	Public Health England
Imogen Tennyson	Sustainable Development Unit
Anne Johnson	ASC/University College London
Sahra Caffarate	Climate Change team at Environment Agency
Nick Jackson	Defra Climate Change Team
Miriam McCarthy	Community and Local Government
Angie Bone	Public Health England
Louise Newport	Department of Health
Juliet Daniels	Climate UK
Rob Hitchen	Defra

B. Health and Emergency Planning indicators

Table B.1 outlines the full list of indicators considered for this project. These have been identified under the four themes identified by the ASC as priorities (namely overheating, emergency planning, social equity and other climate-related risks to health) as under the four categories (namely exposure, vulnerability, actions and impact).

Seventy-nine indicators were originally identified by the interim report, HR Wallingford 2013, with four identifiers later added to this list. However, to maintain the original numbering order, these were added to the list of indicators in the appropriate place, with an appropriate suffix. Therefore, for example, the indicator titled "number of properties/people at significant risk of flooding" has been placed between indicators 35 and 36 with the ID number 35a. This gives a total of eighty three potential indicators to assess.

From the list of eighty three indicators, most were not considered suitable to assess for a number of reasons, the most common of which was due to a lack of suitable data. From this list, twenty-two indicators were therefore identified for analyses, and these are highlighted in red as below:

indicator assessed in report

indicator not assessed in report

For those indicators not assessed in this report, no entries have been added under the methodology, purpose and data headings in Table B.1.

Table B.1: Health and Emergency Planning Indicators (Category of risk – Overheating: Indicator type – Exposure)

ID	Indicator title	Methodology	Purpose	Data
Category of risk – Overheating: Indicator type - Exposure				
1	Number of days the daily maximum temperature exceeds the 93rd and 95th percentile and the daily minimum temperature is below the 10th percentile of the all-year daily maximum and minimum temperature distribution for each government region (see Armstrong, 2010).	Use National Climate Information Centre 5km gridded observed data to produce population weighted temperatures on a daily basis for each government region based on the maximum observed daily temperature.	Daily deaths and hospital admissions tend to increase as the external temperature increases above the 93rd percentile, and decrease below a low threshold, particularly for those with pre-existing respiratory and cardiovascular disease.	Data available for number of days on a regional basis over the period 1960 to 2011.
2	Number of days the daily maximum temperature on the London Underground exceeds certain temperature thresholds.			
3	Trends in urban and rural temperature.	Trends in urban and rural locations for up to 6 cities based on gridded observed data.	as 1 above	
4	Number of heatwave alerts.	Under the Heat-Health Watch system, the Met. Office forecast heatwaves defined by forecasts of day and night-time temperatures, which vary within each region. There are 5 levels, from 0 to 4.	as 1 above	Number of different levels issued for each region available over the period 2004-2013.
5	Area of urban greenspace and bluespace.	Use property density of 500 properties per km^2 to identify urban areas. Use MasterMap Natural category to identify the amount of greenspace and bluespace in those urban areas for 2001, 2008 and 2011.	Urban Heat Island effect is related to the amount of urban greenspace and bluespace with the effect more pronounced where there is less greenspace and bluespace. Trends in urban greenspace and bluespace can give an indication of the mitigation of the UHI effect.	Percentage of greenspace and bluespace in urban areas available for 2001, 2008 and 2011.

ID	Indicator title	Methodology	Purpose	Data
6	Number of hot and humid days per year.			
Category of risk – Overheating: Indicator type - Vulnerability				
7	Vulnerable people in urban areas.	Based on urban areas, use census data to identify number of people over 75 and under 5 living in different areas.	Urban areas tend to be warmer than the surrounding rural areas resulting in greater risk of mortality and morbidity for certain vulnerable groups, particularly for those with pre-existing respiratory and cardiovascular disease.	Data available for number of people on a regional basis from the 2011 census.
8	Building types around the country.	Can use the NRD (National Receptor Database) from the EA to identify flats, terraced, semi-detached and detached properties.	Different property types have different thermal properties. Changing property types by region will give an indication of the potential risk relating to building overheating.	Number of properties by type available on a regional basis.
9	Standard Assessment Procedure (SAP rating) (a measure of insulation in homes).	The Standard Assessment Procedure (SAP) is a methodology used by DECC to assess and compare the energy and environmental performance of dwellings. This is available nationally for people aged under 60, 60-74 and over 75.	Older people tend to be more susceptible to extremes of heat and the energy performance of their dwellings would give an indication of vulnerability. As most of the energy performance assessment is geared towards insulation this will however skew the results towards performance in colder temperatures.	Mean SAP rating by dwelling type and tenure available for 1996 and 2001 to 2011.
10	Indoor temperatures for different building types (homes, hospitals, care homes, schools, offices, commercial buildings etc.).			
11	Number of hospital admissions with cardiovascular illnesses.			

ID	Indicator title	Methodology	Purpose	Data
12	Number of hospital admissions with respiratory illnesses.			
13	Age distribution of population.	Available from ONS data. Ranges are 0-4, 5-7, 8-9, 10-14, 15, 16-17, 18-19, 20-24, 25-29, 30-44, 45-59, 60-64, 65-74, 75-84, 85-89, 90+.	Identify areas that have greater numbers of people in age groups that are likely to be more vulnerable.	Age distribution available by output area from 2011 census.
14	Number of people in at-risk occupation groups.			
15	Average time population spends indoors/outdoors.			
Category of risk – Overheating: Indicator type - Action				
16	Uptake of cooling measures in buildings and transport (air conditioning etc.).			
17	Degree of ventilation in homes, offices, schools, hospitals and care homes.			
18	Uptake of changed working hours by businesses.			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
19	Implementation of heatwave plans in care homes.			
20	Number of local authorities implementing/monitoring action plans for elderly during hot weather.			
21	How many older people are visited.			
22	Buildings with passive cooling.			
23	Evidence that local authorities know where their vulnerable people are.			
24	Amount of monitoring of indoor temperatures.			
Category of risk – Overheating: Indicator type - Impact				
25	Reduced productivity of workforce.			
26	Number of heat-related deaths.	Previous work has been done on this by Ben Armstrong over the period 1993 to 2006, Armstrong (2010). Although this is a modelled indicator, the method used can investigate how deaths from heat may be changing through time based on adaptation as well as changes in population.	Risk of death increases at higher temperatures, particularly for certain groups (those with cardiovascular/respiratory illnesses etc.).	Number of people available on a regional basis from 1993 to 2006.
27	Number of heat-related hospital admissions.			
28	Number of heat-related hospital admissions (Asthma).			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
29	Levels of thermal discomfort in buildings/transport.			
Category of risk – Emergency Planning: Indicator type - Exposure				
30	Number of extreme weather events (trends in very wet days)	Use National Climate Information Centre 5km gridded observed rainfall data to produce population weighted number of single-day events above the 1961-1990 90th and 99th percentile both seasonally and annually. Investigate whether something similar can be considered for wind, although unlikely.	Trends in extreme weather can give an indication of whether these events are increasing and additional measures that may need to be taken to deal with them.	Number of days available on a regional basis from 1961 to 2011
31	Severe weather warnings			
Category of risk – Emergency Planning: Indicator type - Vulnerability				
32	Number of insurance claims for different extreme events.			
33	Number and location of vulnerable people that would need special assistance in the case of an extreme weather event.	Data are available on number of pupils in schools (census), number of beds in care homes (census) via FoI requests, number of beds in hospitals (and capacity for the last two years - HSE), number of people over 75 (census), number of people who report a disability (census), number of people in a nursing home (GPDATA), Number of disability allowance claimants (HSCIC).	People who potentially would need special assistance in the case of an extreme weather event. The "groups" of people to be considered will, on discussion, be a sub-set of those given under the methodology.	Number of people available by output area for 2001 2008 and 2011.
34	Degree of spare capacity in hospitals currently (e.g. most are running at 90% for example so not a lot of redundancy in the system).			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
Category of risk – Emergency Planning: Indicator type - Action				
35	Number of properties/people signed up to the Environment Agency's flood warning service.	The Environment Agency collects and store the number of people signed up to this service.	Gives an indication of how prepared people are for a flooding event.	Number of people by local authority for 2008 and 2011.
35a	Number of properties/people at significant risk of flooding.	Available as part of the National Flood Risk Assessment.	Gives an indication of how prepared people are at risk of flooding.	Number of people by output area for 2008 and 2011.
36	Community risk registers.			
37	Number of local authorities with emergency evacuation plans for vulnerable people.			
Category of risk – Emergency Planning: Indicator type - Impact				
38	Number of flood incidents attended by the fire service (as a percentage of total call outs).	Number of flood incidents attended by the fire and rescue services.	For an indication of trends in the number of people that need rescuing and if this means that more resources need to be devoted to emergency services for better preparedness.	Number of incidents by FRS from 2009-10 to 2012/13.
39	Financial losses from extreme weather events (for different sectors).			
40	Number of working/school days lost from extreme events.			
41	Time between flood event and people returning to their homes.			
42	Numbers of deaths from flooding.			
43	Homes without water/electricity due to a flood event.			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
Category of risk – Social Equity: Indicator type - Vulnerability				
44	Number of households/people from lower socio-economic groups living in areas at significant risk of flooding.	This can be done via the indices of deprivation. It has been done in a previous indicators project, so the results will be copied across to this report. In addition, we could utilise data collected as part of the JRF report.	Gives an indication of those most likely to be less resilient in the face of climate change.	Number of properties by local authority for 2008 and 2011.
45	Number of at risk building types (caravans, basement flats) in areas at flood risk.			
46	People living alone			
46a	People living in Fuel Poverty.	PHOF indicator 1.17 number of people in fuel poverty.	Vulnerability indicator for winter deaths.	Number of people by city/town for 2011.
Category of risk – Social Equity: Indicator type - Action				
47	Number of hospitals with flood defences/heatwave plans.			
48	Number of care homes implementing flood plans/heatwave plans (repeated from overheating).			
49	Numbers of people accessing food banks.			
50	Number of households/businesses with flood insurance.			
Category of risk – Social Equity: Indicator type - Impact				
51	Deaths of people aged over 70 from extreme events.			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
52	Deaths of people in lower socio-economic groups from extreme events.			
53	Number of adults and children with mental health impacts following a flood. There is no data for children.			
Category of risk – Other Climate-Related Risks to Health: Indicator type - Exposure				
54	Concentrations of ground level O_3, PM, NO_2, (e.g. days with concentrations over a certain threshold).	Trends of selected monitored sites representative of urban and rural areas within England. This metric will consider O_3 only.	Daily deaths and hospital admissions tend to increase as the concentration of certain air pollutants increase (although more influenced by emissions than climate). This is particularly the case for those with pre-existing respiratory and cardiovascular disease.	
55	Levels of indoor air pollutants.			
56	Flowering season timing for different allergenic plants.	Natures Calendar record first occurrences of budburst and first flowering for a number of trees, grasses and weeds. These include alder, ash, hazel, oak(pediculate and sessile), silver birch and timothy (grass).	Climate change is likely to result in a change in the start and end date of the pollen season for different allergenic plants.	First flowering and budburst for different allergenic plants over time periods in some cases back to the 1920s.
57	Pollen counts from Met. Office.			
58	Storm frequency/magnitude.			
58a	Sea levels above 1990-1999 empirical 1 year level.	Assessment of the number of times the empirical 1 year level, determined from 10 years of data is exceeded at the 52 NTSLF locations.	Gives an indication of the potential risk of coastal flooding around the English coastline.	Number of occurrences for each port, from varying dates back to the 1920s.

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
59	Levels of indoor dampness/mould.	The English Housing Survey outlines the number of houses with rising and penetration damp and condensation/mould for the period 1996-2011 based on sample surveys every year based on age bands of under 60, 60-74 and over 75.	To give an indication of houses that expose inhabitants to health risks related to dampness and mould. The survey is based on an assessment of a sample number of houses.	Number of houses on a national basis for 1996 and 2002 to 2011.
60	Area/length of coastal stretches with low water quality (based on Bathing Water Directive).			
61	Area/length of coastal stretches with low water quality (based on Bathing Water Directive).			
Category of risk – Other Climate-Related Risks to Health: Indicator type - Vulnerability				
62	Number of people with respiratory illnesses (e.g. asthma, allergic rhinitis, emphysema).			
63	Average time population spends indoors/outdoors.	PHOF indicator 1.16 has utilisation of outdoor space for exercise/health reasons.		Percentage utilisation of outdoor space for exercise/health reasons by city/town for 2011/12 and 2012/13.
Category of risk – Other Climate-Related Risks to Health: Indicator type - Action				
64	Public awareness campaigns on risks from UV/Sunshine.			
65	Deployment/uptake of warning systems.			
66	Air quality measures to reduce ozone, PM and NO2.			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
67	Control measures for invasive plants.			
68	Degree of ventilation in homes, offices, schools, hospitals, care homes.			
69	Number of homes/schools/hospitals/offices monitored for indoor air quality.			
Category of risk – Other Climate-Related Risks to Health: Indicator type - Impact				
70	Number of skin cancer cases.			
71	UVR exposure.	Data of measured UVR are available at a number of sites around the UK. This can therefore be done for a number of representative regions around the UK.	Risk of melanoma and non-melanoma cancer increases with an increase in UVR exposure.	
72	Number of deaths from respiratory illnesses linked to air pollution.			
73	Numbers of hospital admissions/GP visits for respiratory problems.			
74	Number of deaths/injuries from storms.			
75	Number of incidences of norovirus/vibrio, etc.			
75a	Harmful algal blooms and jellyfish incidence.			

ID	Indicator title	Methodology	Purpose	Current single snapshot, past trends, projections
76	Ambulance calls (Percentage of Category A calls against temperature).			
77	Ambulance calls (Percentage of respiratory calls against temperature).			
78	Incidence of vector borne diseases			
79	Food poisoning.			

C. Fire and total incidences data

Table C.1: Number of fire incidents and total incidences attended by each FRS authority

Code	Fire and rescue authority	Flooding 2009-2010	Flooding 2010-2011	Flooding 2011-2012	Flooding 2012-2013	Total 2009-2010	Total 2010-2011	Total 2011-2012	Total 2012-2013	Prop 2009-2010	Prop 2010-2011	Prop 2011-2012	Prop 2012-2013	annual rate 2009-2012	Rank annual rate 2009-2012	Population	Areaha	Density
KA	Avon	224	307	200	540	3,204	3,148	2,899	3,104	7.0%	9.8%	6.9%	17.4%	105	4	1069583	132608	8.06575
GB	Bedfordshire	128	144	101	156	1,520	1,619	1,160	1,218	8.4%	8.9%	8.7%	12.8%	9	24	615061	123543	4.978518
JY	Berkshire	137	145	97	130	2,165	1,469	1,344	1,410	6.3%	9.9%	7.2%	9.2%	-2	34	861870	126198	6.829522
JC	Buckinghamshire	88	184	172	140	1,595	1,694	1,575	1,404	5.5%	10.9%	10.9%	10.0%	17	21	754104	187357	4.024949
GC	Cambridgeshire	82	143	100	94	1,542	1,508	1,328	1,165	5.3%	9.5%	7.5%	8.1%	4	30	804841	338962	2.374428
BE	Cheshire	73	195	53	185	1,552	1,908	1,299	1,425	4.7%	10.2%	4.1%	13.0%	37	11	1027709	234278	4.386705
AC	Cleveland	183	105	41	101	1,795	1,767	2,150	2,081	10.2%	5.9%	1.9%	4.9%	-27	44	557227	59656	9.340646
KC	Cornwall	97	96	60	310	1,519	1,658	1,597	2,119	6.4%	5.8%	3.8%	14.6%	71	6	532273	354619	1.500973
BC	Cumbria	244	128	63	243	1,018	1,024	925	961	24.0%	12.5%	6.8%	25.3%	-0	33	499858	676656	0.738718
ED	Derbyshire	115	170	54	128	2,138	1,931	1,564	1,697	5.4%	8.8%	3.5%	7.5%	4	29	1018438	262473	3.880162
KV	Devon & Somerset	241	339	229	888	6,992	7,277	7,304	8,413	3.4%	4.7%	3.1%	10.6%	216	1	1663714	1015747	1.637921
KT	Dorset	107	93	144	201	2,242	1,952	2,161	2,142	4.8%	4.8%	6.7%	9.4%	31	15	744041	265255	2.804999
AD	Durham	254	147	95	307	1,361	1,207	1,033	1,295	18.7%	12.2%	9.2%	23.7%	18	20	618806	242354	2.553317
JE	East Sussex	402	388	339	373	3,411	2,943	2,721	2,608	11.8%	13.2%	12.5%	14.3%	-10	38	800040	179122	4.466451
GE	Essex	389	400	312	471	5,315	5,040	4,572	4,106	7.3%	7.9%	6.8%	11.5%	27	17	1724950	366952	4.700749
KG	Gloucestershire	120	195	94	347	1,819	1,823	1,903	2,525	6.6%	10.7%	4.9%	13.7%	76	5	596984	265325	2.250011

Code	Fire and rescue authority	Flooding 2009-2010	Flooding 2010-2011	Flooding 2011-2012	Flooding 2012-2013	Total 2009-2010	Total 2010-2011	Total 2011-2012	Total 2012-2013	Prop 2009-2010	Prop 2010-2011	Prop 2011-2012	Prop 2012-2013	annual rate 2009-2012	Rank annual rate 2009-2012	Population	Areaha	Density
JH	Hampshire	162	170	136	167	3,721	3,199	3,028	3,202	4.4%	5.3%	4.5%	5.2%	2	31	1759726	376925	4.668637
FE	Hereford & Worcester	102	234	62	182	1,917	1,875	1,606	1,799	5.3%	12.5%	3.9%	10.1%	27	18	749646	392025	1.912241
GH	Hertfordshire	292	348	364	242	2,517	2,210	2,124	2,150	11.6%	15.7%	17.1%	11.3%	-17	40	1116062	164307	6.792558
DH	Humberside	125	232	121	277	1,999	2,165	1,965	2,126	6.3%	10.7%	6.2%	13.0%	51	8	917647	351728	2.608965
JT	Isle Of Wight	38	71	19	77	799	769	733	690	4.8%	9.2%	2.6%	11.2%	13	23	138265	38016	3.637012
JK	Kent	157	115	63	98	5,410	4,886	4,264	3,706	2.9%	2.4%	1.5%	2.6%	-20	42	1727665	373556	4.624916
BL	Lancashire	281	353	149	378	3,141	2,940	2,393	2,659	8.9%	12.0%	6.2%	14.2%	32	14	1460893	307509	4.750725
ES	Leicestershire	84	175	57	109	2,100	1,994	1,577	1,696	4.0%	8.8%	3.6%	6.4%	8	25	1017697	253771	4.010299
EC	Lincolnshire	177	156	72	359	3,981	4,323	4,519	5,139	4.4%	3.6%	1.6%	7.0%	61	7	713653	592062	1.205369
GN	Norfolk	194	48	21	129	3,012	2,766	2,158	1,560	6.4%	1.7%	1.0%	8.3%	-22	43	857888	537056	1.59739
DN	North Yorkshire	158	326	125	509	1,744	1,946	1,621	2,010	9.1%	16.8%	7.7%	25.3%	117	3	796427	830955	0.958448
EM	Northamptonshire	95	161	108	223	1,454	1,503	1,456	2,823	6.5%	10.7%	7.4%	7.9%	43	9	691952	236397	2.927072
AN	Northumberland	165	75	44	130	764	648	564	621	21.6%	11.6%	7.8%	20.9%	-12	39	316028	501302	0.630415
ET	Nottinghamshire	122	140	51	113	2,527	2,248	2,074	2,101	4.8%	6.2%	2.5%	5.4%	-3	35	1091482	215939	5.054596
JX	Oxfordshire	90	107	115	197	1,722	1,220	1,154	1,285	5.2%	8.8%	10.0%	15.3%	36	13	653798	260492	2.509863
FH	Shropshire	80	114	40	63	975	951	888	663	8.2%	12.0%	4.5%	9.5%	-6	37	472770	348762	1.355568
FT	Staffordshire	115	202	37	232	2,454	2,224	1,840	2,075	4.7%	9.1%	2.0%	11.2%	39	10	1097497	271373	4.044238

Code	Fire and rescue authority	Flooding 2009-2010	Flooding 2010-2011	Flooding 2011-2012	Flooding 2012-2013	Total 2009-2010	Total 2010-2011	Total 2011-2012	Total 2012-2013	Prop 2009-2010	Prop 2010-2011	Prop 2011-2012	Prop 2012-2013	annual rate 2009-2012	Rank annual rate 2009-2012	Population	Areaha	Density
GS	Suffolk	6	4	26	54	1,039	936	825	808	0.6%	0.4%	3.2%	6.7%	16	22	728163	380018	1.916126
JS	Surrey	281	279	249	302	3,036	2,629	2,609	2,581	9.3%	10.6%	9.5%	11.7%	7	27	1132390	166250	6.811376
FS	Warwickshire	61	85	15	10	1,625	1,599	1,337	668	3.8%	5.3%	1.1%	1.5%	-17	41	545474	197508	2.761779
JW	West Sussex	291	338	226	820	2,737	2,485	2,301	2,899	10.6%	13.6%	9.8%	28.3%	176	2	806892	199049	4.053728
KW	Wiltshire	136	164	142	228	2,642	2,574	1,722	1,591	5.1%	6.4%	8.2%	14.3%	31	16	680137	348544	1.951364
KL	Isles Of Scilly	1	6	2	3	4	11	5	11	25.0%	54.5%	40.0%	27.3%	1	32	2203	1637.47	1.345368
BG	Greater Manchester	431	612	285	450	5,093	5,138	4,677	4,539	8.5%	11.9%	6.1%	9.9%	6	28	2682528	127603	21.02244
BM	Merseyside	236	404	145	220	2,802	2,859	2,573	2,447	8.4%	14.1%	5.6%	9.0%	-5	36	1381189	64488	21.41774
DS	South Yorkshire	75	28	15	99	2,586	1,738	1,426	1,383	2.9%	1.6%	1.1%	7.2%	8	26	1343601	155153	8.65984
AT	Tyne & Wear	211	154	116	319	2,346	2,396	2,118	2,224	9.0%	6.4%	5.5%	14.3%	36	12	1104825	54005	20.45776
FM	West Midlands	773	1,226	550	345	6,765	7,287	6,222	5,114	11.4%	16.8%	8.8%	6.7%	-143	45	2736460	90164	30.34986
DW	West Yorkshire	151	259	94	219	3,726	3,618	3,429	2,795	4.1%	7.2%	2.7%	7.8%	23	19	2226058	202927	10.96973
H	Greater London	7,288	7,014	6,281	6,703	41,988	37,694	34,733	33,674	17.4%	18.6%	18.1%	19.9%	-195	46	8173941	157215	51.99209
	Total	15262	16,779	11,884	17,871	155,814	146,799	133,476	134,712									

D. Average number of people per property

England average and deprived areas average

This section describes the method to calculate the average number of people per household in England and the average number of people per household in the top 20% of deprived areas in England. The definition of deprivation is the English Indices of Deprivation (https://www.gov.uk/government/collections/english-indices-of-deprivation).

Abbreviations

IMD = 2010 English Index of Multiple Deprivation

LSOAs = Lower Super Output Areas (The geographical area for which the data is held)

Data Used

- 2010 English Index of multiple deprivation
- UK Census 2011 KS101EW (To get population in households)
- UK Census 2011 KS105EW (To get households)
- Lookup 2001 LSOAs to 2011 LSOAs (There was a slight boundary change between 2001 and 2011 Census).

Method

- Use the lookup table to translate between the IMD LSOAs (from 2001) and the 2011 LSOAs by which the population and households are referenced.
- Add the population and households for each LSOA as follows:
  - Population variable = KS101EW: Lives in a household
  - Households variable = KS105EW: Household Composition: All categories
  - Make sure the Total is used from the Rural Urban field, not any of the subgroups
- To get the England average, sum the population and households for all records and divide by each other
- To get the top 20% deprived areas average, add a criteria to the group by query where the IMD rank is less than or equal to 6496.

Results

Criteria	People per Household
Average of all England LSOAs	2.36
Average of top 20% deprived England LSOAs	2.37
Average of top 1% deprived England LSOAs	2.20

E. Peer review comments and responses

Table E.1: Peer review comments and responses

No.	Reviewer	Comments	HR Wallingford Response
1	Anne Johnson (ASC member)	In preparing for climate change, this report has set out to identify measurable indicators of exposure, vulnerability, impact and action which from available national level data, which in general can provide trends over time. HR Wallingford originally produced a large set of potential indicators that they have contracted to 22 for which key data are available. The choice of indicators has thus inevitably been driven by data availability rather than by 'ideal indicator'. Thus predictably the majority of indicators relate to exposure(11) and vulnerability(6) rather than to action and impact. This is an outcome in itself! It emphasises the paucity of data or national monitoring systems on both the uptake and impact of adaptation actions. In the medium term, it will be important to develop such systems, perhaps through the PHE and others in order to assess preparedness and to advise on policy. Even amongst the indicators used, there is some where data remain surprisingly sparse (e.g. timeseries on heatwave alerts).	Comment noted. No action required.
2	Anne Johnson (ASC member)	Given the difficulties of obtaining data on many of the proposed indicators, the team have made a good job of analysing and summarising the relevant data.	Comment noted. No action required.
3	Anne Johnson (ASC member)	Page 20: I was surprised there was no archive of heatwave alerts. If this is to be useful indicator, the mechanism must be put in place both to retrieve the old data and to set up the system for the future.	Comment noted. No action required.
4	Anne Johnson (ASC member)	P22: the analysis of urban green space and its decline is useful and important. It is also relevant to our work on flooding, SUDS etc.	Comment noted. No action required.
5	Anne Johnson (ASC member)	P26 table 3.7 useful analysis. It wasn't immediately obvious that the unit on the table thousands, and this differs from the format in 3.8. It would be helpful if this were consistent.	Comment noted. Values in Table 3.7 have been changed to be consistent with Table 3.8.
6	Anne Johnson (ASC member)	Figure 3.15 while these are useful data for the current situation, even a short-term forward look requires population projections. These are regularly produced by ONS and some data on projections would be helpful in the preparation of the report, since we can expect not only a larger population but one with an increasingly elderly population. Preparedness plans will need to take account of this.	Population projections (or any other future projections) were not part of the remit for this report, and have therefore not been considered. The ASC will consider these in their progress report. A clarification has

No.	Reviewer	Comments	HR Wallingford Response
		It is not immediately obvious that the figures are England and not the UK. The first sentence of text in this section refers to the UK. The table should be labelled appropriately.	now been added to all Figures and Tables where applicable to indicate that they are in England.
7	Anne Johnson (ASC member)	Page 32. The descriptive analysis of heat related deaths is important and is largely well set out. I wondered why timeseries only went to 2006? It seems important to have more recent data. The commentary addresses the relationship to heatwaves in the relevant years but it would be helpful to see this alongside the quantitative data on number of very hot days for each year. Furthermore, now that we have a heatwave plan, it will be important with more recent data to try to understand whether the heatwave plan is reducing the number of heat related deaths for a given severity of heatwave. For the time being there are probably not enough data points but we should endeavour to have the relevant data to understand this in the future. For this we need both data on the timing and extent of implementation of the heatwave plan.	We agree that it would be better to have mortality data extending beyond 2006, however, given the scope of the project, the time scales and resources, we have concentrated on previously published data which spans the period 1993-2006. Future work would aim to expand the data to the present day.
8	Anne Johnson (ASC member)	Fig 3.16 I found the key difficult to read and couldn't work out which area the top line represented	Comment noted. This is a difficult balance between presenting all regions on one graph for ease of comparison, or one region per graph and hence increasing significantly the number of figures in the report. However, as this reports feeds into the ASC annual report, and they have been provided with the raw results, we feel that the way this and other similar figures are presented is acceptable.
9	Kathryn Humphrey (project manager)	Page 17 fig 3.8- could you add the time period (1960-2011) to the description of the graphs.	This has been added
10	Kathryn Humphrey (project manager)	Page 21- still not sure about including permeable in the greenspace component because is it really greenspace? Gravel etc.? Could you explain this in the text.	Permeable has been included in the greenspace component as it will be

No.	Reviewer	Comments	HR Wallingford Response
			correct in the majority of cases. No change to report/results.
11	Kathryn Humphrey (project manager)	Page 22- could just add that these two groups are in particular vulnerable to heat, hence looking at numbers in urban areas.	This has been added
12	Kathryn Humphrey (project manager)	Page 23- change “there are few local authorities near the coast where over 75s make up >9%” to “there are many local authorities………”	This has been changed
13	Kathryn Humphrey (project manager)	Page 27- you state that SAP isn’t reliable to look at trends but then confidently give the trend. Might need a bit of finessing.	The results are presented to a common SAP, SAP09. This statement has therefore been removed as it applied to comparing trends based on different SAPs, which is not the case. The reference to SAP09 has also been highlighted and added to each graph.
14	Kathryn Humphrey (project manager)	Page 27- I showed the SAP graphs to the committee and they were a bit sceptical of the best fit lines as you would expect an S shaped curve to start appearing as the level approaches 100. Is it possible to leave the best fit lines off?	The curves are s-shaped, but it is not clear due to the relative small range of data available. The best fit lines have therefore been left on the figures, and no change has been made to the report.
15	Kathryn Humphrey (project manager)	Page 29- isn’t the most at risk group the over 75s rather than over 85s?	The over 85s are at higher risk. This is noted in Hajat et al., 2014 (Figure 4). No change made to the report.
16	Kathryn Humphrey (project manager)	Page 29- is the sentence meant to be that there’s a similar relative popn under 20 as over 70 rather than under 70? I presume by relative you mean numbers of people in each age class.	This has been corrected, and changed to over 60, rather than 70.
17	Kathryn Humphrey (project manager)	Fig 3.15 and table 3.9 need a date associated with them.	Census date has been added
18	Kathryn Humphrey (project manager)	Fig 3.19- typo in the title	This has been corrected. Thanks for spotting this.

No.	Reviewer	Comments	HR Wallingford Response
19	Kathryn Humphrey (project manager)	Page 34- worth also saying that Jenkins used a much longer time period (I think since 1766)	The comparison was 1961-1990 and 1971-2000, so a different, shorter time period. This has been added to the report.
20	Kathryn Humphrey (project manager)	Page 39- could you also just say in the text what the total number of pupils is nationally for 2013? Same for nursing home patients, hospital beds and people with disabilities?	These have been added for pupils, nursing home patients, hospital beds and those receiving disability living allowance.
21	Kathryn Humphrey (project manager)	Fig 3.30- could you include a second map showing the absolute number as for the other examples?	This has been added.
22	Kathryn Humphrey (project manager)	Fig 3.31- you've swapped the colour scheme around for this one so blue is more, any reason for that? Makes it a little confusing for the reader.	These have been changed to make them consistent with the rest of the report.
23	Kathryn Humphrey (project manager)	Fig 3.32- one of the local authorities in the middle is greyed out for some reason	This has now been removed/corrected.
24	Kathryn Humphrey (project manager)	Indicator 3.13- EA have updated the NAFRA bandings. Might be worth adding a sentence to say this	Footnote has been added to the report.
25	Kathryn Humphrey (project manager)	Page 50- could you add what the total number of LAs is	This has been added to the report.
26	Kathryn Humphrey (project manager)	Fig 3.36- the title and actual maps seems to have gone awry – the right hand one is total numbers not proportion. Could you make the sample year the same (2012/13) and just plot total number and proportion of all call outs?	This has been changed as suggested to a sample year 2010/11.
27	Kathryn Humphrey (project manager)	Fig 3.37- which FRA is the outlier in the top right hand corner? Is it possible to include a key with which dot is which FRA so we can see which ones are above the line?	This has now been highlighted, however, the attention of the reader has now been drawn to the raw results in Appendix C.
28	Kathryn Humphrey (project manager)	Page 58- there's no trend for rural areas here which is different from other findings that suggest background levels of O3 are increasing while urban peak ozone is decreasing.	In general annual mean ozone in the UK has generally increased over the last decade or so in urban areas, mainly due to the reduction in NOx which tends to destroy ozone. Changes in rural areas are

No.	Reviewer	Comments	HR Wallingford Response
			less marked and show variation with location and time, for example sites in the north of the UK are more influenced by the hemispheric background trend, whereas those in the southeast UK are influenced more by emissions from Europe. But in general, rural annual mean trends are unclear. No change required.
29	Kathryn Humphrey (project manager)	Page 59- would be good to explain briefly how nature's calendar decides on first flowering etc. as this will vary across the country. Is it the first instance that any flowering/bud burst is seen, or the average across the country? If it's the first incidence this might explain in part why the data is so scattered.	A footnote has been added to the report, and a link added to the website where this is defined in more detail.
30	Kathryn Humphrey (project manager)	Page 70- is the erythemal dose the same as the units you have on the y axis of the graph? Also can you explain what the eff means on the units of the y axis	The units on the y axis of the graph are the same as the erythemal dose. The caption has been changed to clarify this. 'eff' has been removed from the y axis label.
31	Kathryn Humphrey (project manager)	General point- we'll need to be able to distinguish between the health and infrastructure reports when referring to them in short-hand as HRW (2014) for both is a bit confusing. Maybe use a and b?	This report only refers to the Infrastructure report for 2014, so no change for this report considered necessary.
32	Kathryn Humphrey (project manager)	Appendix C- will you be adding all the data tables to appendix C?	Only the fire statistics data tables are here. The title of the Appendix has been changed to reflect this, and other raw data will be given to the ASC who can make it available on request.
33	Anna Mavrogianni (UCL)	Table 2.1, p. 2 (9/100 in the PDF) Indicator 4: Are the thresholds used to activate such alerts likely to change in the future? If so, it would be important to note this in order to ensure continuity and uniformity of metrics longitudinally. Indicator 6: How are 'hot' and 'humid' defined?	Indicator 4 : It is not known if the thresholds are likely to change in the future, but ASC have noted this as a potential issue for this indicator. Indicator 6: This was not assessed partly

No.	Reviewer	Comments	HR Wallingford Response
			as it was difficult to define these terms.
34	Anna Mavrogianni (UCL)	Table 2.1, p. 3 (10/100 in the PDF) Indicator 7: Should we distinguish between different types of heat vulnerability (age, physical and mental illness, mobility, income, social isolation etc.) as these would be potentially tackled in different ways? Indicator 9: SAP ratings are not proxies for only levels of thermal insulation but energy efficiency and environmental performance in general. Also, as in my comment about Indicator 4 above, in certain cases, due to changes in the SAP methodology, ratings from different years may not be directly comparable unless generated using the same version of SAP.	The ASC has noted that heat vulnerability has many facets, and this will be picked up in the progress report. Age seems to be the major factor for vulnerability to heat however, so if we can only measure one indicator, this seems the best to focus on. Indicator 7 : This is touched on briefly in the discussion in Section 3.5, however, as far as the report was concerned, it was only possible to consider those over 75 and those under 5. No change therefore required. Indicator 9 : This section has now been rewritten to address these comments.
35	Anna Mavrogianni (UCL)	Indicator 16: Taking into account that passive cooling measures are mentioned later in Indicator 22, does Indicator 16 only refer to mechanical/active cooling systems? Indicator 22: Does this include shading systems?	Indicator 16 relates to mechanical cooling systems. Indicator 22 would include any approach that would be considered to be passive cooling, including shading systems.
36	Anna Mavrogianni (UCL)	Table 2.1, p. 5 (12/100 in the PDF) Indicator 45: Taking into consideration the existing evidence about at risk building types for overheating (top-floor purpose-built flats etc.), I was wondering if a similar indicator could be provided for overheating? My understanding from the analysis of Indicator 8 in section 3.6.1 is that this has already been done.	Indicator 45 : This is covered as noted in indicator 8.
37	Anna Mavrogianni (UCL)	Table 2.1, p. 6 (13/100 in the PDF) Indicator 68: How is this different to Indicator 17 in terms of data collection?	Neither of these indicators were considered further due to lack of data and not being considered a priority. No further comment required.
38	Anna Mavrogianni	p. 8 (15/100 in the PDF)	This has been re-phrased.

No.	Reviewer	Comments	HR Wallingford Response
	(UCL)	I'm not sure I fully understand this sentence: "These have been chosen using equations that are considered to best suit the data series, rather than equations that give the closest fit to the data."	
39	Anna Mavrogianni (UCL)	p. 13 (20/100 in the PDF) "Apart from location, an important factor determining the temperature related health impacts is housing design, heating, ventilation, cooling and insulation." I would also add thermal mass, shading, and internal heat gains.	Report has been changed to reflect comment.
40	Anna Mavrogianni (UCL)	p. 14 (21/100 in the PDF) "In order to estimate the intensity of the UHI, we calculated the difference between urban and rural minimum temperatures for each of the 5 locations, and investigated the trend in UHI intensity over the period from 1960-2011." Maximum temperatures were also considered (but perhaps the focus was on night time heat island intensities)? "[…] since we assume that in the very centre of the city, the extent of urbanisation will not have changed significantly since the 1960s, although of course the nature of the building type may have changed." The volume of traffic and other sources of anthropogenic heat emissions are also likely to have increased since the 1960s.	First comment: The focus was on night time heat island intensities and hence the calculation of trends in UHI was carried out using the minimum temperature in urban and rural areas (Figure 3.9). However, we also wanted to look at how maximum temperatures might have changed over time in urban and rural locations, so we included maximum temperature in the first part of the analysis. No changes to report made. Second comment: This has been added to the text.
41	Anna Mavrogianni (UCL)	p. 21-22 (28-29/100 in the PDF) Whilst absolute surface area levels for greenspace and bluespace are important, these factors could also be presented in relation to housing, i.e. green/blue area per resident, distance of properties from nearest park etc. Other urban morphology characteristics that may influence the formation of heat islands and microclimate, such as built form density, height/width of urban canyons, area of non-water absorbent humanmade surfaces could also be examined. As the latter is already included in the analysis of Ordnance Survey data, % ratio of water permeable to impermeable surface areas could also be calculated.	This is something that could be done but would require additional time and effort that was not available on this project. No change made to report, but this has been noted by the ASC and will be picked up on in the progress report

No.	Reviewer	Comments	HR Wallingford Response
42	Anna Mavrogianni (UCL)	p. 26 (33/100 in the PDF) "Additional risk factors for flats are […]" The type and insulation levels of the roof are also important determinants of overheating risk.	Report has been changed to reflect comment.
43	Anna Mavrogianni (UCL)	p. 27 (34/100 in the PDF) "Figure 3.12 to Figure 3.14 show results for different tenure types over the period 1997/7 to 2011/12." Were all SAP ratings produced using the same version of SAP? "However, conversely, this would also indicate a corresponding increase in overheating risk during the summer months, although this is dependent on whether effective ventilation has been installed." There is no direct inverse relationship between winter thermal efficiency and summer overheating. It is a complex interaction between insulation, thermal mass, internal heat gains, ventilation and external weather. In fact, certain insulation measures could help reduce indoor overheating. Furthermore, the term 'installation of effective ventilation' appears to imply that only mechanical ventilation means could be applied to mitigate overheating; in many cases, natural ventilation alone has the potential to reduce internal summer temperatures, if used strategically, e.g. cross ventilation, night time ventilation combined with thermal mass etc.	First comment : Yes, all SAP ratings were produced using the same version of SAP. This has been clarified in the report. Second comment : This section has been revised to reflect the comments made.
44	Debbie Hemming (Met Office)	P. 18. Figure 3.9 (trends in urban heat island). The large jumps in some of these time series ie. Manchester ~1973 and 1985, and Nottingham ~1990, are surprising. I wonder if they may be caused by inhomogeneities in the datasets potentially linked with, for example instrument changes, urbanisation, others non-climate factors which cause one grid point/station to vary from others around it. These gridded datasets are really means for general spatial comparisons, rather than comparisons of individual grid boxes. I don't have a good suggestion on what could be done to test this because the area of most of the urban areas studies cannot be compared with multiple adjacent grid boxes, but I expect Mark McCarthy would have some suggestions on how best to represent the UHI given the available data and whether the approach taken here is acceptable.	The gridded datasets are not the ideal source of data, however we were limited by which data we could freely use from the Met Office, and MIDAS station data was not an option. We did contact several Met Office colleagues to ask about the suitability of using the NCIC gridded data in this context, and they were of the opinion that the gridded data would show trends in urban temperature. Although there were some limitations in the methodology, we used the best data

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			we had available since this indicator was requested as a key indicator to assess. No further changes made to report.
45	Debbie Hemming (Met Office)	P. 33. I am concerned with the population weighting for precipitation, indicator 30 Number of extreme weather events (trends in very wet days). The large spatial variability in precipitation could make the averages biased towards drier regions of UK (due to the higher precip regions of Scotland and higher altitude regions in UK tend to have less population). As the authors have suggested on p.34 this could explain why their indicator trends are inconsistent with previous published data on heavy rainfall days which shows significantly greater levels of rainfall in the north-west. I would like to suggest that some additional analyses are performed comparing this indicator, Number of extreme weather events (trends in very wet days), with the same indicator but without it being population weighted. This should show whether the trends are related to the population weighting or not.	This has been considered in further analysis by removing the population weighting, and it makes no noticeable difference to the results. The report has been changed to reflect this.
46	Debbie Hemming (Met Office)	P. 17. Small point, it would be good to see on Figure 3.8 'whisker lines' (as in box-whisker plots) to represent the interannual variability. This would help to judge how the differences in trends between the different city trends and urban/rural compare with variability.	We agree that some more analysis into the interannual variability would be advantageous. However, this is slightly beyond the scope of the report but could be considered in future work.
47	Mike Davies (UCL)	Indicator 3 - Trends in urban and rural temperatures With regards to the estimation of the trend in UHI intensity, why was it not not possible to attempt this for London? Other authors have done so (e.g. Wilby). I didn't understand the reasons given for not doing so and I would have expected some reference to this previous work.	The grid cells were chosen so that a city centre cell could be compared with a nearby undeveloped grid cell. In the case of London, it was not possible to select a nearby undeveloped cell, since most of the area was urbanised. We acknowledge there are limitations based on the availability of data and the use of gridded data (we were not able to use the MIDAS data). The other 5 cities chosen had

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			nearby undeveloped grid cells, so a similar analysis with London and a distantly located rural spot would have had some inconsistencies compared with the other cities. We included the central London time series more for information than for a comparison with the other cities. Future work will expand on this analysis and investigate other datasets. Regarding the reference, we had included a similar London reference (Jones et al 2009) but we have now added the Wilby ref. and included some text on the London trends.
48	Mike Davies (UCL)	Indicator 5 - Amount of urban greenspace and bluespace The micro-climatic impact of such spaces require some understanding of their location and proximity to dwellings etc. as Anna points out.	See reply to comment 41. This issue has been noted by the ASC and will be picked up in the progress report.
49	Mike Davies (UCL)	Indicator 8 - Building types There has been a lot of previous work undertaken on this area - see the recent DCLG literature review for example. A useful summary of recent work is given at http://www.arcc-network.org.uk/overheating/. My feeling is that this section seems very brief and perhaps lacking in depth with respect to the many issues involved.	There is currently little data available to assess and make substantive conclusions. The introduction has been expanded, however, there is currently little to say until more data becomes available at later dates. The ASC will discuss this in more detail in the progress report.
50	Mike Davies (UCL)	Indicator 9 - SAP This section seems rather simplistic - the relationship between SAP and overheating is complex and this does not seem to be captured/discussed here.	See reply to comment 43.
51	Mike Davies (UCL)	Indicator 35a - flooding The impact of different energy efficiency interventions will be important - e.g. cavity	This is out of scope for this indicator, but the ASC have noted for possible inclusion

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		wall insulation on drying out times for example. There has been some relevant work carried out in this area e.g. Taylor, J., Biddulph, P., Davies, M., & Lai, K. M. (2013). Predicting the microbial exposure risks in urban floods using GIS, building simulation, and microbial models. Environ Int, 51, 182-195.	in the progress report
52	Mike Davies (UCL)	Indicator 59 - Dampness mould Has exactly the same methodology been used to determine 'damp problems' from 1996 - 2011? I think that some attempt to further discuss the apparently declining trend would have been useful.	It is believed that the English Housing Survey has used a consistent methodology to determine damp problems in different years. A discussion of the declining trend for this report was not included as the potential reasons are more difficult to accurately clarify.
53	Aleksandra Kazmierczak, University of Manchester	p. 1 The terms 'exposure' and 'vulnerability' need to be defined. These are contested terms and their understanding varies among professionals. Also, who or what is exposed and vulnerable is not clear - is the Cabinet Office's definition of people vulnerable in crisis used here?	These have been added as footnotes on page 1.
54	Aleksandra Kazmierczak, University of Manchester	Is the overall focus of the report the vulnerability of the UK population or the vulnerability of the health and emergency planning system? The report states that the indicators in this report should help to monitor changes over time in preparedness, and from the sentence that precedes this statement it could be understood that it is the preparedness of health and emergency planning. This would imply analysing the characteristics of the health and emergency services to a greater extent than it is done in this report, which looks in more detail at the characteristics of the population.	This report has a focus of both the vulnerability of the UK pupation and the health and emergency planning system. Some of the results from the parallel project on infrastructure are also of relevant to this report, and this has now been noted in the introduction.
55	Aleksandra Kazmierczak, University of Manchester	If the focus of the report is the UK population, it should be stated that the vulnerability and exposure are used to describe the characteristics of the population. Alternatively, additional indicators on preparedness of the health/emergency planning system could include: The number of ambulance / fire / police stations / hospitals / care homes actually at risk of flooding (under vulnerability / exposure). This would require only simple	Some of these indicators (number of assets in areas of flood risk) are covered in the infrastructure project. Others were either not highlighted, had a lack of data, or were not considered suitable during the consultation stage. Some of these

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		processing of the information about these locations against NaFRA/Surface Water Map. Access of population to the health services. This could be obtained e.g. from the ONS accessibility statistics. Percentage of health and well-being strategies covering the impacts of climate change and including adaptation strategies.	datasets e.g. health service statistics are being collected in house by the ASC. The percentage of health and wellbeing strategies including consideration of climate change is an interesting one. Although this doesn't in itself mean that action is being taken to reduce vulnerability, it could imply a greater awareness of the issues.
56	Aleksandra Kazmierczak, University of Manchester	Measuring 'action ' is confusing – action would mean e.g. implementation of a policy (coverage of climate impacts in health and well-being strategies could be an indicator). Whilst some of the indicators of 'action ' in table 2.1 reflect that (e.g. 17, 21), some describe the desired outcomes, the degree of exposure (e.g. 35a – number of people at significant risk of flooding) or even the vulnerability (e.g. 49 – number of people accessing food banks – surely the higher the number the higher the vulnerability?).	This is a generic problem with indicators in that some can span different categories depending on how they are looked at. This has been dealt with by the ASC in previous reports and will be covered in the annual progress reporting.
57	Aleksandra Kazmierczak, University of Manchester	p.2 'Other climate related risks to health' – please clarify what is meant by 'other' – other than high temperatures and flooding?	It is felt this is covered in the description; "other risks" was a category devised by Defra to include the low confidence risks outside of heat/cold related risks. It will not be used as a category in the progress report.
58	Aleksandra Kazmierczak, University of Manchester	Surface water flooding is not being considered as climate-related hazard in this report at all, which can be seen as a serious omission.	This was reported on for the ASC 2012 progress report, so the ASC will use that data in its assessment for the 2014 progress report (there will be a whole chapter with an update on flood risk).
59	Aleksandra Kazmierczak, University of	What is the intended spatial unit for applying the indicators? National scale, urban-rural, local authorities, 1km grid, SHAs? There is not much consistency between the indicators. Also, the trends in indicators are shown for different timeframes.	In most cases we are restricted by the format the data comes in. Timeframes are again restricted by what we have and

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	Manchester	Would it be possible to make the timeframes more uniform, e.g. 2001-2011?	what is available. This is highlighted in Section 3, which has been slightly changed to reflect this comment.
60	Aleksandra Kazmierczak, University of Manchester	An important aspect of vulnerability currently missing is tenure – the census data suggests that there has been a very big increase in the proportion of private tenants. We know from the literature that this groups is more likely to suffer from climate impacts due to lower uptake of contents insurance, little control over the property, shorter residency times etc.	Good point. However, this was not noted in the consultation process. May be appropriate to consider this in a future assessment. No change made to report.
61	Aleksandra Kazmierczak, University of Manchester	Which NAFRA data is being used – the dataset is frequently updated, it would be useful to know which version is being used.	The version of NaFRA used for this is 2011. The ASC asked for it to be included again, but there was no additional resource to update the findings using the latest version of NAFRA (2013).
62	Aleksandra Kazmierczak, University of Manchester	Indicator 5: Amount of urban greenspace and bluespace The cooling effects are different for different types of greenspace, see e.g. Armson et al (2012) (http://www.sciencedirect.com/science/article/pii/S1618866712000611). Trees should be considered separately from grass. The Mersey Community Forest designed a methodology for identifying green space using MasterMap. Please see: http://www.greeninfrastructurenw.co.uk/resources/A_Green_Infrastructure_Mapping_Method.pdf This methodology can help to identify trees in urban areas. Also, is it certain that all 'multiple' class polygons in MasterMap are gardens? The Mersey Forest method only looks at those 'multiple' polygons in direct proximity to houses (area <2,500m2 & within 1m of MM DESCGROUP 'Building' with area <250m2 and >25m2) Urban areas could more easily be identified using the Land Cover Map 2007 – urban and suburban areas are distinguished as land cover classes in this dataset.	It is interesting to see what the Mersey Community Forest did, but something like that wouldn't have been achievable in the timescale we had. It's designed to be used for smaller areas than the whole of England and makes extensive used of aerial photography that we don't hold. No change made to report on this point. The urban part of the Land Cover map was considered for identifying urban areas but was not found to be suitable for the task. No change made to report on this point. We specifically modified the definition of urban areas so that large greenspaces in urban areas were taken into account and

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		This would help to avoid the generalisation to 1km grid cells and would also help to pick up smaller settlements. Have you considered the edge effect - the fact that large green spaces in cities are not taken into consideration means that the urban areas around them could be identified as more exposed to heat than they actually are. The cooling effect of green spaces outside the boundary of urban area does not seem to be considered either. Also, only large parks have been found to have a cooling effect on surrounding areas, extending by up to 1km beyond their boundary, thus they should be considered as part of the urban area rather than excluded from the analysis. The changes in the amount of greenspace over time could be partially a result of the changes in the baseline data. The MasterMap accuracy has changed over the years. For example, the two generalised land use database datasets (GLUD 2001 and GLUD 2005) cannot be compared directly as time series due to the changes in the underlying MasterMap data (see http://neighborhood.statistics.gov.uk/dissemination/MetadataDownloadPDF.do?downloadId=19576&nsjs=true&nsck=false&nssvg=false&nswid=1680). Thus I believe it could be an issue here, too. Could this be highlighted or discussed? There is also a need to state the sources of uncertainty associated with the assumptions made about the characteristics of 'multiple' polygons and the urban creep over time – the results presented here are presented in a very definite manner, whilst they are based on modelled rather than actual data. Table 3.5 should specify that 'greenspace' is a sum of 'natural' and the permeable elements of 'multiple' – it is not clear otherwise.	also smaller settlements. This is explained in the text. No change made to report on this point. Noted. Addition made to report. This is covered in the explanation of the method, with a reference to a more detailed explanation (HR Wallingford, 2012). Table has been modified to reflect comment.
63	Aleksandra Kazmierczak, University of Manchester	Indicator 7: Vulnerable people in urban areas The groups listed in the introduction to the indicator are also more vulnerable to surface water flooding, in particular in urban areas due to impermeability of the urban surfaces – are you planning to cover surface water flooding in the report? How have you defined urban areas here? Is it done in the same manner as for indicator 5? Or e.g. are the local authorities/MSOAs/LSOAs classified into urban	Surface water flooding has been addressed in other research reports, and will be included as part of an update on flooding in the ASC's 2014 progress report. Urban areas are defined using Census

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		and rural? Why is only old age selected as an indicator of vulnerability? There is also an unnecessary overlap with indicator 13. Looking at e.g. proportion of people with long term limiting illness, or the proportion of people renting rather than owning their homes could provide a better additional proxy for vulnerability rather than double-counting age. Alternatively, comprehensive indices of vulnerability to high temperatures and flooding have been developed by the University of Manchester for a JRF project (Lindley et al., 2011) based on census, IMD and other indicators. These have been updated recently and will be available online by mid-2014. The individual indicators used and the composite indices could be mentioned in the report. Figure 3.10 – how are the classes defined? Standard deviation, natural breaks? Is it the same classification for both maps? The maps are shown for the entire country, so what is the logic behind identifying vulnerable (older) people in urban areas only? N.b. older people in coastal and rural locations could be equally vulnerable and with worse access to health and emergency services.	urban/rural split. Old age has been chosen as the key indicator for overheating risk as the academic literature suggests this is the most important aspect of vulnerability, although obviously there are many other aspects as well (people with disabilities, school children, people in temporary accommodation are also included in section 3.11. The ASC will be using the Lindley data in its progress report. Figure 3.10, the classes are defined to give an approximate even spread of Local Authorities in each band. Urban areas tend to be warmer than rural areas, resulting in greater risk for vulnerable (older) groups from heat related diseases (see Table B.1, Appendix B).
64	Aleksandra Kazmierczak, University of Manchester	8: Building types around the country This indicator only presents only the proportion of flats in house types at the national level. Is it possible to include different housing types, too? For example, houses with basements are more likely to be damaged by flooding. Are houses with the lowest floor below ground level covered in the National Receptor Database? Census data on houses with basements is available for 2001 (census) but was not collected in 2011. Is it possible to identify the number of top floor flats as the type of property the most exposed to high temperatures? Could the national receptor data be compared against the census 2001 data in terms of the number of flats or is it modelled data?	Basement flats were not included as an indicator as the data on this in the NRD was considered to be of insufficient quality. The NRD reported approximately 8000 basement flats for the whole of England. The NRD only identifies upper floor properties, although top floor flats could possibly be identified by using the number of ground floor flats (making the assumption that a ground floor flat has a

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		Could the indicator be presented finer scale, e.g. local authorities/SHAs? Is this indicator related to vulnerability, or should it be listed under exposure (as the building type increases exposure of people living in it to climate hazards)?	top floor). The national receptor data could be compared against the census 2001 data, however, this is out of scope for this project. It could be presented at a finer level e.g. LAs, and this has been provided in this form to the ASC for their progress report. The indicator is listed under vulnerability, however as you state, it could equally be listed under exposure.
65	Aleksandra Kazmierczak, University of Manchester	13: Age distribution of population This is an unnecessary repetition of indicator 7. Does this indicator describe the vulnerability of population to climate impacts or the pressure on health and emergency services now and in the future due to changing age distribution of population? This is not clear. Tables 3.9 and 3.10 are difficult to interpret. I would suggest either presenting graphically as population pyramids or reducing the number of age bands, for example 0-16, 16-64 (working population) and 65+, which would make sense if you want to represent the pressure on health services.	We agree that indicators 7 and 13 are similar, however, these were accepted in the consultation process for the final list of indicators as separate indicators. The indicator relates to the vulnerability of the population as noted in Table 2.1. Tables 3.9 and 3.10 are considered okay by the ASC; they will be re-plotting the data for the progress report.
66	Aleksandra Kazmierczak, University of Manchester	33: Number and location of vulnerable people that would need special assistance in the case of an extreme weather event Does the indicator correspond with the Cabinet Office definition of people vulnerable in crisis (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/61228/vulnerable_guidance.pdf)? If this is the case, there seem to be some groups missing, e.g. the homeless, those cared for by relatives (could be assessed by a number of people providing unpaid care – census 2001); minority language speakers (census 2011 data on the number of people not born in the UK, and also by non-UK born with short length of residence in the UK could be considered as a	The missing classes are those where there is no national data with a time series that could be found in the time available for this report. No change to report appropriate.

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		proxy); Individuals supported by health or local authorities; tourists – e.g. number of hotel beds? The variables listed in this section are effectively separate indicators – should they be considered separately to be consistent with the rest of the report? If not, then indicator 7 - vulnerable people in urban areas could consider more dimensions than just the proportion of older people. Number of people in nursing homes is also available from census 2011 for spatial units as small as output areas, and could be compared against 2001. Is comparing 2010 and 2011 meaningful or should we be looking at a longer period to make conclusions about temporal change?	
67	Aleksandra Kazmierczak, University of Manchester	35a: Number of properties/people at significant risk of flooding The most up-to-date NaFRA dataset should be used in my opinion (due to the improving quality of the data) rather than results from previous studies. Similarly to the MasterMap data, could you estimate to what extent the change in the situation over the years is associated with the changing exposure to flooding, and to what extent with the changing data quality? The number of properties at risk from surface water flooding should also be considered.	Agreed. However, this has been taken from a previous ASC study, HR Wallingford 2012, an no new analysis was carried out as the resource to do this wasn't available for this project
68	Andy Haines, LSHTM	This appears to be a wide ranging and generally comprehensive report. Unfortunately I didn't have time to read through it in detail.	Comment noted. No action required.
69	Andy Haines, LSHTM	The indicators should reflect issues where the policy implications are relatively clear and where climate change is responsible for a substantial attributable risk – so for example I am not convinced about the use of skin cancer incidence because behavioural factors may be dominant including overseas travel. Likewise the levels of fine particulate air pollution are very important for public health but may not be much affected by climate change. These are likely to be more affected by policies to reduce greenhouse gas emissions. There is much detail on pollen and small shifts in pollen season but these are of limited importance for public health.	Point noted. Skin cancer was removed as a potential indicator for the reasons noted. Likewise for particulate matter, though ground level ozone was included. We chose to look at timing of flowering to look for possible convergence as this was an issue in 2013 for hayfever sufferers and there didn't appear to be data on this. The ASC has noted that this isn't a major public health issue.

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70	Andy Haines, LSHTM	At present the indicators only reflect outcomes within the UK but perhaps threats to the UK arising outside the country should be considered –e.g. the spread of vector borne disease in Europe or effects on the UK of increases in food prices causing unrest in North Africa etc. The European Centre for Communicable Disease Control in Stockholm is potentially important for collaboration.	This is out of scope for this project, but the ASC are considering these risks as part of their progress report and for the next UK Climate Change Risk Assessment.
71	Andy Haines, LSHTM	The likely effect of climate change on winter mortality is still controversial – a recent paper in Nature Climate Change suggests that winter mortality may not decrease with climatic change.	The ASC have noted the paper, and may refer to it in their progress report if it is deemed appropriate.
72	Andy Haines, LSHTM	There is a need for an appropriate balance between indicators reflecting risks and impacts. Ultimately impacts are a reflection of whether the UK population is adapting to climate change. It will be important to assess potential confounding factors that could be alternative explanations of changes in impacts e.g. behaviour change unrelated to climate change.	This is a process of what data is available and what can be done. The lack of data on impacts and action for this sector is noted and will be discussed in the ASC's progress report. No change suitable for this report.
73	Andy Haines, LSHTM	Maximum use of existing datasets should be made – for example the NERC/MRC funded MED-MI project aims to link health and environmental data and make this available to the research community. There needs to be coordination to ensure that best use is made of such initiatives.	Point noted, but these issues are addressed in several points above. It mainly reflects what data was available and the timescale of the project. The ASC will look at the MED-MI data.
74	Andy Haines, LSHTM	The potential for maladaptation should be explicitly considered – so for example the development of coastal salt marshes for protection purposes may result in increased mosquito populations. Although the focus here is on adaptation where possible policies should aim to integrate mitigation and adaptation responses e.g. in housing design.	This is out of scope for this project, but will be considered by the ASC for their progress report.
75	Andy Haines, LSHTM	Although some of the indicators reflect the presence of plans to address extreme events these may not necessarily reflect the effectiveness of such plans in practice. So for example the presence of flood protection plans for hospitals may not be as effective as not building them on flood plains to start with.	Point noted, but out of scope for this project. The ASC will pick up on this issue in their progress report.
	Environment	Indicators 1 and 3- It would be helpful to have some discussion of the differences	This would be useful, however, this is a

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	Agency	between the gridded data used and potential observations from a single location within the grid square, whether at a standard meteorological station, or more relevant to many peoples' experience, indoors. This is one example of the difference between what is easily managed from a data point of view and what people may experience or measure for themselves.	significant piece of work and not directly relevant to this project, particularly in relation to time available. No changes made to project.
76	Environment Agency	Indicator 9- I would like to see some justification for the assumption made that a good SAP score, as well as measuring efficiency for heating purposes, also measures efficiency for cooling purposes. This may depend on the strength of the assumption about ventilation practices.	These comments have been addressed in comments 43 and 50.
77	Environment Agency	Indicator 13- I would like some acknowledgement of the use of age as a proxy for a raft of other more relevant physiological measures. A number of specific (usually age-related) syndromes contribute to the vulnerability of the elderly (poorer cardio-vascular performance, poorer temperature detection, poorer sweat production, confusion, conservatism etc).	The age vulnerability is just in relation to overheating risk in this context and is the strongest determinant of vulnerability to heat on its own. However, as you say, this is caused by the reasons you mention so this has been added to the report.
78	Environment Agency	Indicator 71, UVR exposure: I would expect that there are medical records that log the incidence of radiation-induced damage to eyes and to skin to complement this impact indicator.	It is not easy to definitively link the incidence of radiation-induced damage to the skin and eyes since any effects would occur over long time-scales and are difficult to attribute. No change made to the report.
79	Miriam McCarthy	ID 38: Number of flood incidents attended by fire service (as % of total call outs) The general view from fire colleagues is that any method to try to improve the data collection and information on flooding and its effects are to be broadly welcomed. There are some concerns around the proposed index. The difficulty with the flood incidents is that they are highly episodic – a few major incidents every so often, and a general low level of on-going response to localised flash flooding. That said, over a long enough time period, the trend information would be interesting, and would probably give a good indication of the level of	Points noted. As Miriam points out, more data will improve this indicator, and it may be appropriate to consider other suitable datasets for future analysis.

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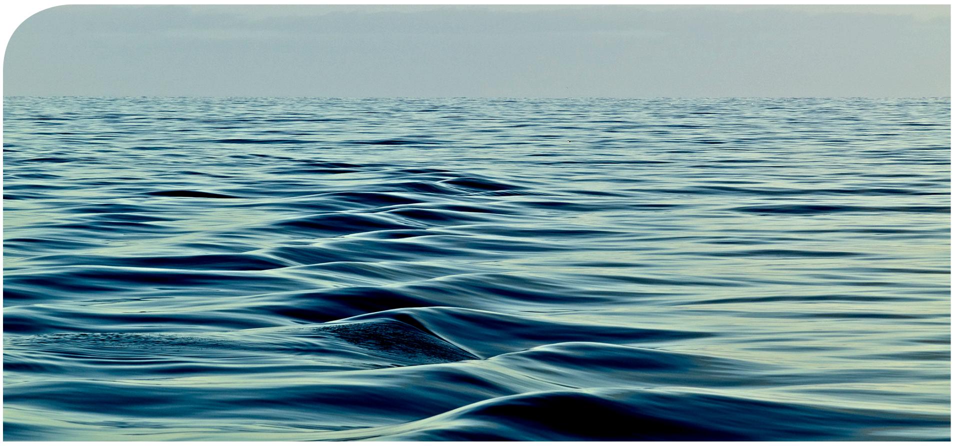
		emergency response to severe weather events. We would need to separate out domestic flooding caused by appliances/plumbing, from those which are more specifically weather related. How to establish that relationship may be easier that it seems. Also there is an established and (we believe) CLG owned Incident Recording System (IRS) which fire services complete following operational incidents. This has been in place for over three years and is building a strong repository of data. Its completion relies on the diligence of operational crews across all FRSs. It is difficult to establish the consistency with which 46 FRSs complete their reports. [Our Fire colleagues are currently investigating ownership and access to this data.]	
80	Miriam McCarthy	Both maps (page 52) suggest London as the location with the highest proportion of flood incidents, and flood incident as a proportion of total incidents. It would be interesting to see how far those maps change if London was treated separately. London is the largest and busiest fire service, however this may have a skewing effect on the data. To base the indicator on population may tend to bias the data towards London, whereas to use a figure such as number of flood incidents as a proportion of river length, or mm of rainfall may indicate a stronger weather related coefficient.	This section has been revised, and specific comments on London relative to other FRAs have been added.

HR Wallingford
Working with water

Public Health England



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