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Heatwaves and mortality in Ireland, planning for the future

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Climate change enhances the vulnerability of Ireland to extreme weather events in terms of potential adverse health impacts. To examine this, the mortality impacts of heatwaves between 1981 and 2006 were analysed, with particular reference to potential differences occurring between urban and rural areas. Heatwaves were identified during five summers: 1983, 1984, 1995, 2003 and 2006. Episodes in the 1980s were seen to have had a greater impact, especially July 1983, with 115 excess deaths recorded in rural areas. Only 14 excess deaths were reported in 2006 and none in 2003. Overall, 294 excess deaths were attributed to heatwaves. Heat is a moderate but real risk in Ireland. In the future, with climate change and the ageing of the population, it may be that more severe heat episodes will result in a larger mortality burden. It is recommended that the relevance of setting up an appropriate heat prevention plan should be considered in Ireland.

Keywords: mortality; heatwave; heat; climate change; Ireland

Introduction

Despite a moderate climate and low urbanisation, heat-related mortality in vulnerable groups is considered a potential threat in Ireland (Environmental Protection Agency 2009). As a mid-latitude country, climatic trends in Ireland tend to be largely consistent with global trends. Mean annual temperatures in Ireland have increased by 0.8°C over the past 110 years and 6 of the 10 warmest years have occurred since 1990. Mean annual temperature records showed a warming evident in two steps, 1910 to the mid-1940s, and 1980–2004. For the 1961–2005 period, minimum temperatures were increasing at a faster rate than maximum temperatures except in winter (Sweeney *et al*. 2002). The number of warm episodes, defined as periods when the maximum temperature is at least 5°C greater than the 1961–1990 climatological mean value for at least six consecutive days, has increased at a number of stations (McElwain and Sweeney 2007). Projected temperature increases range between +1°C and +3°C by 2100, compared to the 1961–2000 mean temperature (Sweeney *et al*. 2003).

In addition, over coming decades, the number of people in the over 74 age group is expected to increase between 273,000 and 284,000 in 2021, compared with 190,000 in

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2002 and 230,000 in the 2011 census. It is also expected that more than 20% of people aged over 65 will be living in Dublin city and county (Connell and Pringle 2004). This ageing of the population accompanied by a changing climate may increase Ireland's vulnerability to extreme heat, and future heatwaves may result in a significant health burden.

Previous analyses of the temperature–mortality relationship in Ireland have found discordant results. While no adverse impacts from high temperatures were reported in Dublin by the European PHEWE project (Baccini *et al*. 2008), an increase in temperature of 1°C was found to be associated with a 0.4% increase in total mortality in Dublin (Goodman *et al*. 2004). An increase in mortality at high temperatures has also been widely observed at a global scale. This includes countries with equable climates and relatively cold summers, although few studies have been conducted at latitudes and with climates similar to Ireland. For example, in Sweden, an increase in 1°C in the summer temperature over two weeks above the 90th percentile (around 21°C) was associated with a 5.1% increase in mortality in people over 65 years [95% CI 0.3:10.1] (Rocklov and Forsberg 2010). In England and Wales, during summer, a 1°C increase in maximum temperature above a heat-threshold set as the 93rd percentile (21–25°C depending on the location) was associated with a 2.1% increase in all causes mortality [95% CI 1.6:2.6] (Armstrong *et al*. 2011, Gasparrini *et al*. 2011). These results indicate that heat could have a non-negligible impact on health in Ireland. A first step is therefore to analyse the past and present impacts of heat in Ireland. In this paper, the mortality impacts of heatwaves that have occurred in the past 30 years were investigated to assist in the planning of relevant prevention and adaptation strategies.

Methods

Daily mean, minimum and maximum temperatures were obtained from Met Éireann for the period from 1981 to 2006. Eleven synoptic stations were selected to cover the whole country. Individual mortality data were obtained from the Central Statistics Office of Ireland for the same period. Mortality data were sorted using the International Classification of Disease (ICD) into total, cardiovascular (ICD9: 390–459) and respiratory (ICD9: 460–519) categories and by two age categories (0–74 and >74 years old). The absence of postcodes limited the ability to perform analyses of the mortality data with a good geographical resolution. County level was the best available spatial resolution, and the location of death was detailed for the main population centres only, thus limiting the possibility of describing the exposure to temperature at the location of death. There was not enough statistical power to perform the analysis at the city level due to the small numbers of daily deaths. The choice was then made to create urban and rural indicators. The urban indicator included the larger urban centres for which mortality data were readily available (Dublin, Cork, Drogheda, Arklow, Dundalk, Galway, Limerick, Waterford and Wexford). Deaths which were not coded in one of these urban centres were classified as occurring in rural areas. This 'rural' category therefore also includes urban centres with a population of 30,000 inhabitants and below (Central Statistics Office Ireland 2011).

Indicators of temperature exposure in urban areas were computed using data from the closest synoptic weather stations to each urban centre (Figure 1): Shannon, Cork, Rosslare, Casement and Dublin. Data from the remaining stations were used to define the rural exposure. These indicators are distinguished as rural or urban temperatures in the

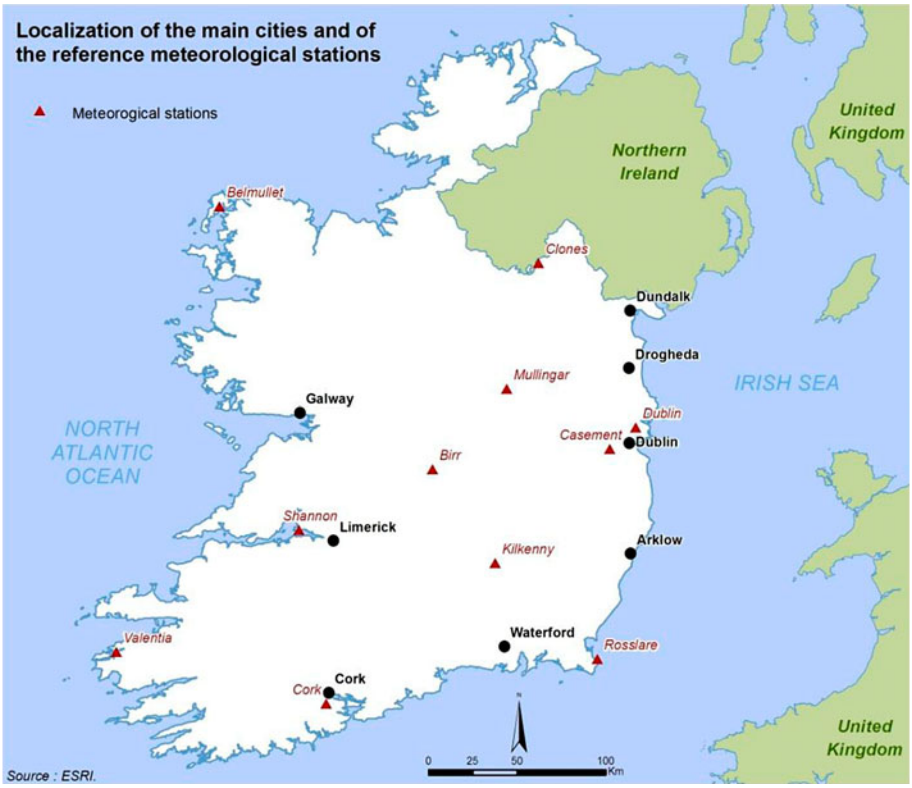

Figure 1. Location of the main population centres and of the meteorological stations.

text below, bearing in mind that they correspond to an average of several meteorological stations.

For both the rural and the urban indicators, a generalised additive model was used to predict the daily mortality based on the daily variations of the minimum and maximum temperatures up to lag 7. Temperatures were modelled by splines with three degrees of freedom. The long-term trends, the seasonality and the day of the week were introduced as confounding factors.

These models were used to assess the mortality attributable to extreme temperatures during heatwave periods. Such periods were not defined on the aggregated urban or rural temperature indicators, but for each station, on the basis of having at least two consecutive days with minimum and maximum temperatures >90th percentile of the monthly distribution of the temperatures observed in the station between 1981 and 2006. The corresponding thresholds are reported in Table 1. Only periods when heatwaves were observed in more than 50% of the stations were included. This definition based on the station was preferred in order to exclude episodes that would have been limited to a small area. Five days were added at the end of the period to allow for a possible lagged effect, as the literature indicates that the mortality peak occurs 24–48 hours after a peak of temperature (Basu 2009).

The excess mortality attributable to temperature during a heatwave was estimated as the mortality predicted by the model from the observed temperature, compared to the mortality predicted by the model from reference temperatures. The reference temperatures

Table 1. Temperature thresholds (P90 of the monthly distribution) used to identify heatwave periods in each station (°C).

		June		July		August	
Station	Threshold	Tmax	Tmin	Tmax	Tmin	Tmax	Tmin
Belmullet	P90	19	12	21	14	21	15
Kilkenny	P90	22	12	25	14	24	15
Mullingar	P90	21	12	23	14	22	14
Birr	P90	22	12	24	14	23	15
Valentia	P90	19	13	21	15	21	15
Casement	P90	22	12	24	14	23	14
Clones	P90	21	12	24	14	23	14
Cork	P90	20	12	22	14	22	15
Dublin	P90	21	12	23	14	22	14
Rosslare	P90	19	13	21	15	21	15
Shannon	P90	22	13	24	15	23	15

were computed as the mean of the meteorological data between 1981 and 2003. All computations were done using R software, especially the mgcv package of the R software (R Development Core Team 2008).

Results

Between 1981 and 2006, 772,942 deaths were recorded, but location was available for only 172,983 (22.4%), which were classified as urban. An error in the coding of some locations was identified in 1986, and that year was excluded from the analysis. Dublin mortality represented 70% of the urban mortality indicator, Cork 16% and Limerick 4%. The remaining deaths were classified as rural. The distribution of age groups by location was similar, with people older than 74 years representing 51% of the urban mortality and 55% of the rural mortality.

During summer months, average temperatures were higher in urban areas, with a mean temperature of 15.3°C contrasting with 14.6°C in rural areas. The warmest years were 1995, 1983 and 2006 (Figure 2). On average, the mortality was higher in 2006 (39 deaths per day versus 36), especially in rural areas. This increase in mortality in 2006 was particularly related to deaths from respiratory disease (Figure 2).

Based on the definition outlined above, heatwaves were observed in a majority of the meteorological stations during the summers of 1983, 1984, 1995, 2003 and 2006. The exact periods are detailed in Table 2. These heatwaves were not long episodes, lasting between 6 and 22 days, but moderately intense.

A major mortality peak attributed to heat was not observed during any of these episodes, as illustrated by Figure 3 in 1983. However, the July 1983 heatwave resulted in approximately 136 excess deaths corresponding to a 12% increase in the total mortality (Table 2). A majority (85%) of these excess deaths occurred in rural areas (+115 deaths [95% CI 96:137]). Some 60% of the deaths were of people older than 75 years. In rural areas, the majority of the deaths occurred from cardiovascular causes (64 [95% CI 50:79]), while this was not observed in urban areas. The 1984 heatwave had a smaller impact in rural areas, resulting in 49 extra deaths [95% CI 29:68], of which 75% were elderly people. In 1995, an excess mortality in elderly people was observed in rural areas in June, but the second heatwave in August had no visible impact. In 2003, a reduction in

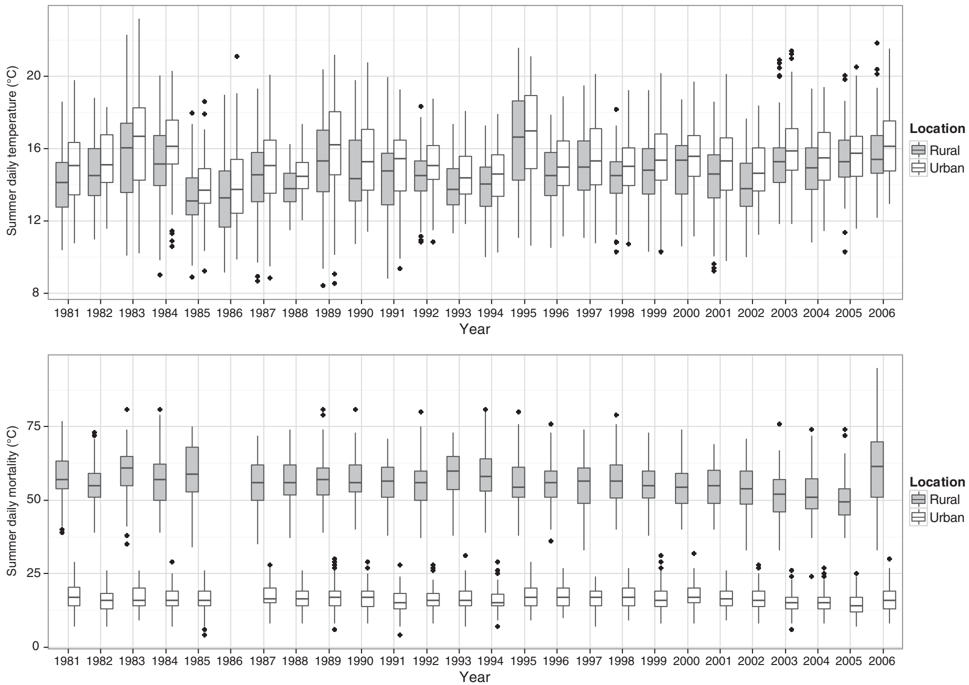

Figure 2. Annual summer mortality and summer temperature distribution in rural and urban areas between 1981 and 2006.

Table 2. Excess mortality (number of deaths) and temperatures during heatwaves in rural and urban areas.

		Excess mortality [95% CI] (number of deaths)				Temperatures mean (min:max) (°C)	
Heatwave period	Areas	Total	>75 years old	Cardiovascular	Respiratory	Tmin	Tmax
5–18 July 1983 14 days	Rural	115 [96:137]	65 [51:79]	64 [50:79]	19 [12:26]	13.6 (10.4:16.1)	23.5 (18.0:28.1)
	Urban	21 [9:33]	16 [7:24]	0 [0:17]	7 [3:11]	14.5 (10.7:17.5)	23.8 (18.5:28.5)
18 July–1 August 1984 14 days	Rural	49 [29:68]	37 [24:51]	22 [7:36]	20 [14:26]	13.9 (10.7:16.2)	22.2 (19.6:25.7)
	Urban	9 [−2:21]	17 [9:25]	0 [-6:10]	3 [−1:6]	14.3 (10.9:16.2)	22.1 (20.2:24.3)
22–30 June 1995 9 days	Rural	9 [−25:43]	36 [26:47]	22 [13:31]	13 [8:18]	11.4 (7.3:14.0)	24.8 (22.4:27.1)
	Urban	−13 [−21:−5]	−10 [−16:−4]	−5 [−15:−1]	2 [−1:5]	12.0 (8.6:14.4)	23.8 (21.3:26.4)
1–22 August 1995 22 days	Rural	9 [−25:43]	−18 [−43:8]	9 [−14:32]	6 [−5:17]	13.2 (9.7:16.3)	24.0 (19.4:27.1)
	Urban	−10 [−29:9]	−8 [−21:6]	1 [−20:5]	9 [2:15]	13.5 (9.8:16.8)	24.0 (20.3:26.6)
4–12 August 2003 9 days	Rural	−45 [−56:−33]	−31 [−40:−21]	−27 [−34:−20]	10 [−15:−6]	13.0 (9.7:14.8)	23.3 (20.5:27.2)
	Urban	13 [6:19]	3 [−2:8]	2 [0:10]	−1 [−3:2]	13.7 (10.9:15.4)	23.6 (22.2:26.4)
22–27 August 2003 6 days	Rural	−7 [−15:1]	−5 [−18:14]	14 [9:19]	−22 [−25:−19]	14.5 (11.6:16.2)	22.0 (19.2:25.2)
	Urban	10 [5:14]	−2 [−5:2]	0 [−4:2]	5 [3:7]	14.7 (11.4:17.1)	21.1 (18.4:24.4)
17–30 July 2006 14 days	Rural	14 [−7:35]	15 [−2:32]	6 [−6:19]	−9 [−18:−1]	13.5 (11.1:15.2)	23.1 (19.9:28.6)
	Urban	−36 [−48:−24]	−25 [−33:−15]	−17 [−24:11]	−1 [−5 :3]	14.0 (12.1:16.2)	23.6 (21.0:26.8)

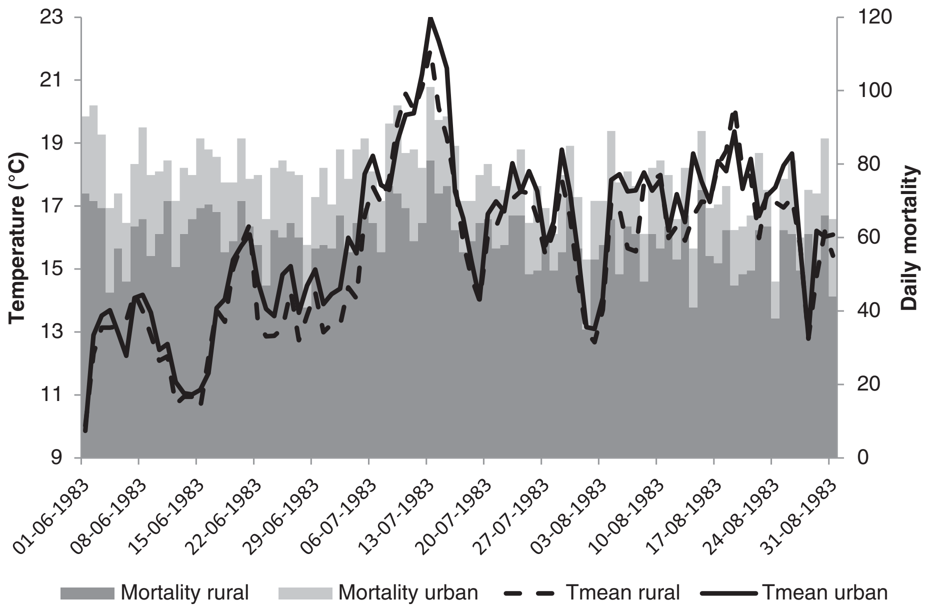

Figure 3. Daily mean temperature and mortality in the rural and urban areas in summer 1983.

mortality was observed during the first episode, while a 10% increase in mortality in urban areas was observed in the second episode. During the 2006 episode, a reduction in mortality was observed in urban areas, and a small increase was observed in rural areas. Overall, a total of 294 excess deaths attributable to heatwaves was estimated, of which 241 was in rural areas, and 53 in urban areas.

Discussion

This analysis confirmed that heat is a moderate but real risk in Ireland. One limitation is the coarse geographical scale used to perform the analysis. Although temperatures can be considered as relatively homogeneous over the country, daily variations or local peaks may be observed, leading to significant differences in the heat exposure of the population. Therefore, the health outcomes and heat exposure cannot be perfectly matched in the rural and urban indicators chosen, which may lead to an incorrect selection of the heatwave periods, and an over- or underestimation of the excess mortality, depending on the location.

The definition used for heatwaves fixes their intensity by setting thresholds but allows variations in their duration. This approach is the most widely used in the literature on the health impacts of heatwaves. In addition to the one presented here, different thresholds were tested, based on the temperature percentiles of the minimum, maximum or mean temperature at different geographical scales. All identified the same periods investigated in this study. Other definitions may be used but it is unlikely that they would identify different episodes, as extremes of heat remains very rare events in Ireland.

The 1983 and to a lesser extent the 1984 heatwaves were characterised by a significant excess mortality, especially in rural areas. More recent episodes were associated with a decreased mortality in rural areas and a slight increase in urban areas. The reasons for these differences may relate to the nature of the heatwaves (long and intense in 1983, as opposed to short spells during other episodes), and to improvements in the health care system. With the prospect of climate change, and with the ageing of the population, it may be that more severe heat episodes will result in a larger mortality burden, as was observed during the July 1983 heatwave.

Despite the limitations introduced due to the use of rough urban and rural indicators, the results are consistent with the literature. The 1995 heatwave, occurring between 30 July and 3 August, resulted in 619 excess deaths in England and Wales (+9% of the total mortality; Rooney *et al*. 1998). During this heatwave, the highest Central England Temperature, a weighted mean temperature for England and Wales derived from measurements at four meteorological stations, was 25°C.

In addition, Ireland is a rural country, and most heat-related studies to date have focused on urban areas, where the impacts are supposedly larger as the population may be overexposed to heat, both because of the additional heat created by the urban heat island (Laaidi *et al*. 2011) and because of less well-ventilated buildings. However, the few studies looking at the impacts of heat in rural areas have also reported an increase in mortality. For instance, during a heatwave in July 1980, mortality increased by more than 55% in St Louis and Kansas city, and by 10% in the rural neighbouring areas (Jones *et al*. 1982). In Australia, the warmest temperatures were associated with a significant increase in mortality in rural areas (Loughnan *et al*. 2012). In Germany, an excess mortality during heatwaves in 1994 and 2006 was observed both in Berlin and in the rural Federal State of Brandenburg (Gabriel and Endlicher 2011). In England and Wales, a similar temperature–mortality relationship was found in urban and rural areas; although a stronger heat effect was observed for those people living in urban areas (Hajat *et al*. 2007).

A short-term societal adaptation to heatwaves is the implementation of heat prevention plans. In many cases, such plans have been developed in reaction to a deadly heatwave, such as in France in 2003 (Fouillet *et al*. 2006) or in Chicago in 1995 (Semenza *et al*. 1996). Indeed, although most of the measures that can reduce the mortality are simple, they are not easily implemented in the absence of a heatwave plan, when people are unaware of the dangers of heat. Preventative measures include advising the public on how to lower the indoor temperature, how to reduce exposure to the sun by keeping in the shade during very hot weather and how to drink and eat regularly. A communication strategy to promote such appropriate behaviour in the population by the health service may be the first and essential step to limit the adverse impacts of heatwaves. As most of the experience on heat-related prevention focuses on urban areas, recommendations and actions specific to the rural settlement would need to be developed, with possibly a special focus on outdoor workers, including farmers.

In addition to implementing a heatwave plan, it is also necessary to improve the surveillance of health data, in particular mortality data. At present, Ireland lacks a really effective and usable health information system (Staines *et al*. 2001). The integrated approach promoted by the Draft Standards for National Health Information Resources (Health Information and Quality Authority 2011) and Healthy Ireland (Department of Health 2012), and especially an improvement in geographical resolution, would also be an asset to any further study of the relationship between health and environmental exposure.

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