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Exploring 167 years of vulnerability: An examination of extreme heat events in Australia 1844–2010

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ABSTRACT

Despite their relative importance in terms of human mortality, extreme heat events have not attracted the same level of study compared with other natural hazards in regards to vulnerability and implications for emergency management and policy change. Definitional confusion and inconsistencies in defining heat related deaths over time have made it difficult to determine an absolute death toll. Notwithstanding these issues, this study employs PerilAUS – Risk Frontiers' database of natural hazard event impacts – in combination with official sources in an attempt to provide a lower-bound estimate of heat-associated deaths in Australia since European settlement. From 1844 to 2010, extreme heat events have been responsible for at least 5332 fatalities in Australia and, since 1900, 4555: more than the combined total of deaths from all other natural hazards. Over 30% of those deaths occurred in just nine events.

Both deaths and death rates (per unit of population) fluctuate widely but show an overall decrease with time. The male to female death-rate ratio has fluctuated and approaches but does not reach equality in more recent times. In line with other studies, seniors have been the most vulnerable age group overall, with infants also over-represented. Policy implications in view of a warming climate and an ageing population are discussed.

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1. Introduction

Earlier studies by Risk Frontiers (Andrews, 1994; Coates, 1996) suggested that, with the exception of disease epidemics, extreme heat events had been the most significant natural hazard in Australia in terms of loss of life, killing at least 4287 persons since European settlement. [The term ''extreme heat event'' is preferentially used in this study rather than ''heat wave'', except when referring to named events and in Section 2.3]. These and more recent studies (e.g., Bi et al., 2011) parallel results from USA, where extreme heat events were responsible for 8015 deaths between 1979 and 2003: more than hurricanes, lightning, tornadoes, floods and earthquakes combined (CDC, 2013).

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The European heat wave of 2003 was one of the first to capture world attention, with an initial estimation of 35,000 *excess deaths* across Europe (e.g., Conti et al., 2005; IPCC, 2011, p. 397; Schär and Jendritzky, 2004; Vandentorren et al., 2006), including over 14,800 excess deaths in France alone (e.g., Fouillet et al., 2006). [*Excess deaths* is the difference between the number of deaths observed and the average number expected for that particular location and time of year – an estimate of the death toll from an extreme heat event often used in place of more accurate data.] More recent work has put the total excess death count in Europe at over 70,000 (Robine et al., 2008).

During 2010 Eastern Europe and Russia experienced an extreme heat event with an estimated excess death count of 55,000 in Russia alone (Barriopedro et al., 2011). These fatalities were related to temperatures and carbon monoxide pollution from extensive wildfires (Shaposhnikov et al., 2014). In the last decade, Australia has witnessed two notable high fatality events: Brisbane, Queensland, February 2004, with an estimated 23% increase in overall deaths (Tong et al., 2010) and January–February 2009, southern Australia, with 374 excess deaths in Victoria – an increase of 62% in overall deaths – and 58 attributed heat deaths in South Australia (BoM, 2009; Department of Human Services, 2009; Johns, 2009).[1]

A study by Lee (2014) examined the occurrence of, and the human casualty from, hot and cold extreme temperature events (ETE) worldwide, held within the International Disaster Database (EM-DAT) 1900–2011. The study identified 422 ETE across 71 countries and, based on event occurrences, numbers killed and numbers affected, identified Australia as a key country 'at risk' from extreme heat. However, despite recent high death tolls and anticipated aggravation of risk in a warming climate, little research has been carried out in Australia on longitudinal mortality counts that explore how vulnerability to this peril is changing over time.

This paper seeks to document a detailed exploration of Australian human mortality using a long time series of extreme heat events and compares this toll with other natural hazards in Australia. Spatio-temporal trends of the vulnerability of different population groups are also investigated. The time period of interest is from 1844 to the present due to quality and quantity limitations in pre-1844 data. Uniquely, this paper examines victims' circumstances and activity at time of death.

1.1. *Australian context – changing climate, demographics and built environment*

Significant changes in temperature and precipitation extremes have occurred across Australia in the 20th century (e.g., Collins et al., 2000; Nicholls et al., 2000; Plummer et al., 1999). The Commonwealth Scientific and Industrial Research Organization (CSIRO) and The Bureau of Meteorology (BoM) report that each decade has been warmer than the previous one since the 1950s (CSIRO and BoM, 2010, 2012). Without adaptive measures, the conjunction of expectations for extreme heat events to be of greater frequency, duration and intensity and an ageing and increasing population suggests an increase in future heat-related fatalities (Alexander and Arblaster, 2009; Keenan and Cleugh, 2011).

Since 1844, Australia's population has increased from approximately 260,000 to 3.7 million in 1900 and 22.3 million in 2010 (ABS, 2008a). This growth has come with greater urbanization and high-density housing, exacerbating the issue through a heat island effect. Furthermore, people are increasingly living in homes not designed to reduce heat stress and more reliant upon air-conditioning (Maller and Strengers, 2011), the operation of which cannot be guaranteed during an extreme heat event.

Based on medium-level growth assumptions, the Australian Bureau of Statistics (ABS) projects the population to grow over the next two decades by 29% to 28.8 million, the number of people aged 65 and over to rise by 91% and those aged 85 and over to more than double (ABS, 2008b).

1.2. *Mortality and vulnerability to extreme heat – current understanding*

Epidemiological studies world-wide have demonstrated that impacts of extreme heat are felt disproportionately within society (e.g., Fouillet et al., 2006; Klinenberg, 2002; Loughnan et al., 2010a; Luber and McGeehin, 2008; Nicholls et al., 2008; Saez et al., 1995; Vandentorren et al., 2006). The most important socio-economic and physiological risk factors identified are age; pre-existing medical conditions; chronic mental disorders; medications; alcohol/narcotics; social isolation; low-economic status; homelessness and strenuous outdoor physical activities (Bi et al., 2011; Bridger et al., 1976; Buechley et al., 1972; Ebi and Meehl, 2007; Fouillet et al., 2006; Hansen et al., 2008; Kinney et al., 2008; Klinenberg, 2002; Loughnan et al., 2010a–c; Luber and McGeehin, 2008; Vandentorren et al., 2006).

Socio-economic and physiological risk factors often overlap. For example, the elderly have reduced thermoregulatory and physiologic heat-adaptation capability and are more likely to experience poor health and to be living alone with fewer social contacts and limited finances (Luber and McGeehin, 2008). Many of the most vulnerable groups also live in substandard housing poorly adapted to extreme heat. Race and sex have been noted as important due to the marginalization of these groups in some societies. Examples include higher death rates for non-white, male populations in USA (e.g., Buechley et al., 1972; Klinenberg, 2002) and females in Paris during the 2003 European heat event, even after controlling the data for age (Toulemon and Barbieri, 2008).

The significance of extreme heat in Australia in terms of human mortality largely escaped public attention until Coates (1996) compared fatalities from different Australian natural hazards. This situation has changed: for example, Bi et al. (2011) provide an overview of the literature, the majority of which has either focused on individual extreme heat events, relatively short periods of time or specific cities or regions. An

[1] Exact comparisons between fatalities in South Australia (SA) and Victoria for the 2009 event cannot be made. The Government of SA have released the exact number of fatalities believed directly related to the event while in Victoria only an excess fatality count is known. Issues of determining attributed fatalities from heat events and the lack of a standardized recording procedure are discussed in Section 2.4.

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