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Exploring the circumstances surrounding flood fatalities in Australia—1900–2015 and the implications for policy and practice

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ABSTRACT

This paper documents the analysis of the circumstances surrounding fatalities due to flooding in Australia between 1900 and 2015. This longitudinal investigation is important to understand changing trends in social vulnerability and to inform efficient and strategic risk reduction strategies. The basis of this analysis was *PerilAUS*, Risk Frontiers' database of historical natural hazard impacts in Australia. This data was augmented and verified using coronial inquest records which provide detailed data concerning the social, demographic and environmental circumstances of each fatality. A statistical analysis of the data was undertaken, examining demographics (age, gender), location (state), seasonality, circumstances surrounding the fatality, environmental factors (e.g. the event intensity) and social factors (e.g. the decisions or actions which led to death). Overall there have been 1859 fatalities identified, with distinct trends in relation to gender, age, activity and reason behind the activity. Flood deaths have been declining. The majority of the fatalities are male (79.3%): however, since the 1960s the proportion of female to male fatalities has increased. Children and young adults (< 29 years) make up the greatest proportion of the fatalities (53.8% of cases where age is known). The highest proportions of fatalities occurred while victims attempted to cross a flood-impacted bridge or road. The recommendations for emergency management policy and practice are discussed, outlining the need for a new approach that accounts for a continuum of measures including regulation and incentive, education and structural intervention.

1. Introduction and background

This paper updates and expands on previous work on Australian flood fatalities conducted by Coates (1999) and Haynes et al. (2009). This is particularly important as floods are ranked second, following heatwaves, in terms of the total number of natural hazard fatalities since 1900 (Coates et al., 2014).

The investigation explores the social and environmental circumstances surrounding all documented fatalities due to flooding in Australia from 1900 to 2015, presenting a longitudinal understanding of changes in vulnerability to flooding over time. This examination provides an evidence base for emergency management policy and resource allocation, and is a first step to enabling efficient and strategic risk reduction strategies. The methodology and analysis employed is based on similar published work on heatwaves (Coates et al., 2014) and bushfires (Haynes et al., 2010; Blanchi et al., 2014).

Globally, flooding is a significant cause of death (World Health Organization, 2014; Jonkman and Kelman, 2005; Ahern et al., 2005). According to the International Federation of Red Cross and Red Crescent Societies (2015) some 59,092 flood fatalities have occurred worldwide between 2005 and 2014. Substantial research into flood-related fatalities has been undertaken by Diakakis and Deligiannakis (2017), Hamilton et al. (2016), Haynes et al. (2009), Jonkman and Kelman (2005), Jonkman et al. (2009) and Kundzewicz and Kundzewicz (2005), Peden et al. (2017) amongst others. A full literature review is contained in the online Supplementary material (link).

2. Methodology

The foundation for this work is the use of the Risk Frontiers' database *PerilAUS*, which contains historical data on the incidence (magnitude and affected locations, etc.) and consequences (property damage and fatalities, etc.) of natural hazard events in Australia. Detailed data ranges from European settlement (1788) to the present day. *PerilAUS* is

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based on material collected from news media, government reports, published literature, jurisdictional coroners' records, the Australian Bureau of Statistics, and registries of Births, Deaths and Marriages for Australia's states and territories.

The data covers the following natural hazards: floods, extreme heat, bushfires, tropical cyclones, earthquakes, hailstorms, landslides, lightning strikes, rainstorms, tornadoes, tsunamis and windstorms. A number of published studies have utilised *PerilAUS,* including: Blanchi et al. (2014), Coates (1999), Coates et al. (1993, 2014), Crompton et al. (2010) and Haynes et al. (2009, 2010).

An important component of the current project was the further detailed examination, where possible, of coronial data relating to flood fatalities. The availability of victims' names in the original Risk Frontiers' database allowed the retrieval of witness and police statements and forensic documents contained in coronial inquest reports. This process was found to be a crucial means of verification and adding further detail to the circumstances surrounding flood fatalities, especially by enabling a better determination of the social, demographic and environmental circumstances of the deceased.

The classification of the data followed the same numerical coding methodology as that developed and outlined in Haynes et al. (2010). The coding scheme was initially developed and refined by the two lead authors who worked together through a number of the fatality records. The wider team then completed the bulk of the coding, with cross-checking of the entire database conducted by the two lead authors.

The data was classified into the following categories:

2.1. Demographics

Age and gender.

2.2. Location, seasonality and flood characteristics

Details of the location where the fatality occurred, the date and time and the physical characteristics of the flood: flood type and severity (e.g. "a one-in-100 event"). Table 2 outlines the detailed coding categories used for flood type and severity.

2.3. Mode of transport

Details on the mode of transport used by the deceased prior to and at the time of their death: walking, in a closed or open vehicle, on a boat or ship, on a makeshift or inflatable raft etc.

2.4. Actions taken and reasoning, awareness and capacity to act

This category classifies the actions taken by the deceased at the time of their death. Where information from witness statements was available it categorises their level of awareness or knowledge of the flooding and possible dangers. Information on the capacity of the victim to act was also captured and coded. Inferring people's decision making, their level of awareness and their capacity to act is problematic, particularly due to the varying levels of detail in the fatality records early in the last century. Where there was not enough information available to make sensible judgments, these deaths were labelled as unknown. Tables 3–9 outline the detailed coding categories used for these classifications.

3. Results and discussion

The total number of individually identified flood-related deaths between 1900 and 2015 was 1859, with an average national annual death rate of 2.91 fatalities per 100,000 people per year.

3.1. Demographics

Fig. 1 shows a time series of fatalities by gender since 1900. The majority of the deaths have been males (79%), a percentage which is statistically significantly greater than 50% ($p < 0.0001$).

Death rates relative to the national population have declined over the years (Fig. 2).

Between 1900 and 1959 there is a significant decrease in the flood fatality rate (slope = −0.05449, $p < 0.02$). This means the fatality rate was decreasing by 0.55 deaths per 100,000 in the population per year. In contrast, from 1960 to 2015 the fatality rate has been decreasing by 0.0645 per 100,000 in the population per year. However, this decrease in flood fatality rate is not statistically significant. The ratio of male-to-female fatalities has steadily decreased over time, with a statistically significant decline ($p < 0.01$) from the 1960s. This indicates an increasing proportion of female fatalities in more recent times. The majority of deaths have occurred in events where two or less people died (67%, n = 1248 in 1076 flood events). Events where 5 or more people have died correspond to 19% of the fatalities (n = 352 in 35 flood events).

A total of 35 people of Australian indigenous heritage are listed within the data set, making up 2% of the total fatalities. However, it is likely that a large proportion of indigenous deaths, particularly during the first two thirds of the last century, were unrecorded and their deaths are underrepresented.

Given the differences in the way of life and the trends seen in the data since 1960, a detailed exploration of the data pre- and post-1960 was conducted. However, the trends seen in terms of demographics, locations and actions taken are very similar in both time periods. Therefore, the results presented below are for the full data set with only unique differences in the recent data, such as fatalities in motor vehicles, explored.

The breakdown by age (Fig. 3, and Table S1 in the Supplementary material) demonstrates the distinct high-risk groups of children and young adults (< 29 years), who make up the greatest proportion of deaths (43%, n = 807 out of 1859). When the gender is examined, the highest proportion of male fatalities are seen in the 10–29 year age brackets (38% of all male fatalities in which age is known) and the highest proportion of female fatalities is seen in the younger 0–19 year age brackets (54% of all female fatalities in which age is known). For both genders these proportions are statistically significantly greater than what would be expected if fatalities were evenly distributed across age ranges. For both genders the proportion of fatalities then decreases steadily with age. Over 50% of the female deaths occur in those under 29 years of age (56%, n = 206) and over 50% of the male deaths occur in those under 39 years of age (51%, n = 756). A detailed examination of the fatalities under 18 years of age by gender shows the heightened vulnerability of males, particularly among two-year olds, children (8–11 years old) and young adults (18 years old). Interestingly, numbers of fatalities are raised for two-year old females and six- and seven-year old females.

In terms of cause of death, the majority died from drowning (57%, n = 1055), followed by those who were likely to have died from drowning (37%, n = 691). The latter group cannot be accurately categorised as drowned due to a lack of specific data about whether drowning, injury, exposure or heart attack was the root cause. As many of the early deaths were often classified as drowning without a proper autopsy it would be most correct to state that 94% of deaths were caused by drowning, with injury, exposure or heart attack likely to be a contributing factor in many of these.

3.2. Location and seasonality

When the location of deaths is examined across Australia (Fig. 4 and Fig. S1), Queensland (38%, n = 702) and New South Wales (37%, n = 683) account for 75% of the overall fatalities. The third highest number of fatalities occurred in Victoria, with 13% of fatalities (n = 245). When population size (Fig. S1) is considered, the heightened level of risk in the Northern Territory is revealed: the fatality rate is