An analysis of human fatalities from flood hazards in Australia, 1900-2015

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Abstract
This paper documents the analysis of the circumstances surrounding fatalities due to flooding in Australia from 1900 to 2015. The basis of this analysis was PerilAUS, Risk Frontiers' database of historical natural hazard impacts in Australia. This data was augmented and verified by the use of coronial records through funding provided by the Bushfire and Natural Hazard CRC. Inquest reports allow additional and more detailed data about the social, demographic and environmental circumstances of the fatality to be determined. A longitudinal analysis of the resulting statistics was undertaken, examining demographics (age, gender), location (state), seasonality and circumstances surrounding the fatality – both environmental (e.g. the event intensity) and social (e.g. factors around the decisions or actions which led to death). The recommendations for emergency management policy and practice are discussed, outlining the need for a new approach which accounts for a continuum of measures including regulation and incentive, education and awareness, structural intervention and consequence management.

Aims
This paper documents the social and environmental circumstances surrounding 1859 fatalities that have occurred due to flooding in Australia from 1900 to 2015. This examination is a fundamental first step to providing an evidence base for emergency management policy, practice and resource allocation and to enable efficient and strategic risk reduction strategies. This is particularly important in the Australian context where floods are ranked second, following heatwaves, in terms of the total number of natural hazard fatalities since 1900 (Coates et al 2014).

This research is the first major milestone from the Bushfire and Natural Hazards Co-operative Research Centre (BNHCRC) funded project "*An analysis of human fatalities and building losses from natural disasters in Australia".*

Background
Despite the significance of flood mortality worldwide, few studies have explored trends and characteristics associated with flood fatalities (Jonkman and Vrijling, 2008). A significant number of flood fatalities have been attributed to unnecessary risk taking behaviors (Jonkman and Kelman, 2005). Where people have deliberately entered floodwaters, reasons for doing so have been to continue their intended travel; engage in recreational pursuits; continue their work; and evacuate or carry out a rescue of a person or pet (Haynes et al., 2009).

Increasingly, flood fatalities are associated with vehicles and not surprisingly, a significant proportion of flood rescues performed by rescue agencies are also of people from vehicles (Haynes et al., 2009).

In western societies, males are usually over represented in fatality statistics (Haynes et al., 2009, Jonkman and Kelman, 2005, Jonkman and Vrijling, 2008, Jonkman, 2014; Diakakis and Deligiannakis 2015). The over representation has been attributed to the high proportion of males who drive vehicles, occupations held by males and the risk taking behavior of males (Coates, 1999, Haynes et al., 2009, Jonkman and Kelman, 2005). The age of flood victims varies across studies. However in Australia, Haynes et al. (2009) found that mortality was greatest between 0-29 and 60-69 years, and FitzGerald et al. (2010) found mortality was concentrated between 10-29 years and over 70 years.

Methodology

The project was completed in two steps: 1) updating the data held within PerilAUS relating to human fatalities from flood events, and 2) statistical analysis to determine the lives lost and the environmental and social circumstances surrounding those fatalities.

The foundation for this work is the use of the Risk Frontiers' database *PerilAUS*, which contains historical data on the impacts and consequences of natural hazard events in Australia. *PerilAUS* is based on material collected from news media, government departments and the published literature. It was deemed a good basis for this project due to the length of period covered, the wealth of descriptive detail concerning the hazard impact and the inclusion of data about any fatalities caused by that hazard. To meet the needs of this project, however, it was recognized that the database needed to be enriched in breadth and detail. Importantly *PerilAUS* contains many of the names of the deceased, which has enabled the collection of detailed information on the circumstances of many of the fatalities from coronial inquest reports. For further information on *PerilAUS* see Haynes *et al.,* (2010) and Coates *et al.,* (2014).

Inquest reports allow additional and more detailed data about the social, demographic and environmental circumstances of the fatality to be determined. Coronial inquests were found to be a crucial means of verification and adding further detail to the circumstances surrounding flood fatalities. In particular, they enabled a better determination of the social, demographic and environmental circumstances of the deceased. Almost all the inquests located revealed additional data, including confirmation of a flood-related fatality rather than a non-natural hazard-related drowning.

In addition, supplementary information on the physical characteristics of flood events was gathered from Australian Bureau of Meteorology (BoM) sources and the print media in order to improve understanding of any relationships between impacts and flood characteristics.

The data has been analysed in relation to informing the understanding of the circumstances surrounding the deaths and how this information could best be utilised for emergency management policy and practice. This has included an examination of the data around the following themes: demographics, cause of death, location of the fatality

and transport, activity and reason behind action prior to death, capacity and awareness, and flood type and severity.

For further details on the methodology and analysis see Haynes *et al.,* (2016)

Results

Overall there have been 1859 fatalities with distinct trends in relation to gender, age, activity and reason. The majority of these deaths occurred in events where two or less people died. The analysis of flood severity against numbers killed per event demonstrates that the majority of these occurred in minor-moderate floods. The greatest percentage of women died in urban settings in relation to a local flash flood or a low-level short duration flood.

The majority of the fatalities are male (79%), however, since the 1960s the proportion of female to male fatalities has increased. Children and young adults (<29) make up the greatest proportion of the fatalities. The highest number of fatalities overall have occurred in QLD and NSW although the deaths per capita population highlight the increased level of risk in the NT. Overall, the majority of deaths occurred between January and March during the summer / monsoon season. A spatial analysis of fatalities between 2000 and 2015 shows that 58% died within 20km of their home.

The highest proportions of male and female fatalities occurred while victims attempted to cross a bridge, causeway, culvert, road, etc on foot or in a vehicle (men: 43.4%, n=639; women: 38.2%, n=139). Of all those who were en route at the time of their death, the greater number were on their way home. For females, the second highest activity at the time of death, accounting for nearly a quarter of all female fatalities, was being engaged in an activity not near a usual watercourse, e.g. driving through town or in their home and surprised by rapid flash flooding. For men this was the third highest cause of death. Being engaged in an activity near the water (bank) was the second highest cause of death for men and the third highest for women. The majority of these victims were recreating, with children and young people (<19 years) accounting for the greatest proportion of these fatalities. A significant cause of these deaths was children playing in or near stormwater drains.

The majority of the victims were capable of independent action and aware of the flood. However, the speed and or depth took them by surprise. An analysis of fatalities by time of day revealed that almost a quarter of all fatalities that entered floodwaters did so in the dark or twilight when visibility would have been poor. However, a higher proportion, over one third perished during the day when visibility is likely to have been better. Higher proportions of deaths occurred among children and females who were following the decisions of others and also among children and youths who were on their own or in a group of children. Of this latter group the majority were boys.

Fatalities that were on foot have decreased slightly through time but remain a high proportion. However, an increase of fatalities associated with motorised vehicles is seen over recent decades. In particular, fatalities associated with 4WD vehicles have increased over the last 15 years. The vast majority of those driving a vehicle were men while the gender breakdown of the passengers is roughly equal. Approximately 20% of the fatalities among children and youth are associated with vehicles, the majority of whom were passengers. The highest proportion of all those in a vehicle perished at night or during twilight when visibility was poor.

Recommendations

Limited research has previously been conducted to evaluate many initiatives historically utilised to reduce the instances of people entering floodwater. Typically, Australian management strategies have relied upon education and rescue interventions as primary management tools. A more holistic behavioural change focus is required, including: education, incentives and consequences including law and regulation and also structural intervention and consequence management (Gissing et al., 2015). These are briefly detailed below:

Education

Both education campaigns and safety messages in public warnings have been the primary strategies used to change motorist behaviour. Roadside flood markers are frequently used to indicate the possible depths of flooding. However, current markers indicate the depth of flooding, but leave motorists to interpret the risk rather than providing them a clear safety message.

Methods for consideration in education and awareness campaigns include:

- Implementation of specific location-based warning systems at high risk locations. These may include broadcasts through car radio systems or lights and sirens.
- Inclusion of educational messages in driver training programs.
- Implementation of a national campaign to deliver consistent messages.
- Enhancement of flood warning systems in flash flood environments.

Incentives and consequences / Law and regulation

Regulation is often used to change behaviour: for example, enforcing speed limits and encouraging seat belt use. Regulation, however, has not been widely employed across all Australian jurisdictions to stop motorists from driving though floodwater. Queensland Police have enforced careless driving charges for motorists entering floodwater, resulting in fines and license disqualification. Laws and incentives that could be considered to influence behaviour may include:

- Motorists required to pay for the cost of their rescue where behaviour is deemed reckless.
- Insurance companies not being obliged to pay claims for vehicles damaged as a consequence of driving through floodwater where motorist behaviour is deemed reckless.

Structural intervention

Structural intervention includes structures to prevent people entering floodwaters, road design which increases the safety of motorists if they were to enter floodwater, and vehicle design. Due to the portable nature of barricades, motorists are able to relocate or drive around them, although often flooding may also occur before authorities can establish barriers. Gissing et al., (2016) identified in a case study of flooding in NSW that a high percentage of motorists ignored road closure barricades.

To enhance the effectiveness of barriers the following could be considered:

- Manning of barricades in high risk areas with personnel with the authority to direct motorists not to proceed, and

- Establishment of automatic gates in high risk areas that are activated remotely or when triggered by a warning system.

Road design in flood prone areas could have a critical influence on the survival outcomes of motorists once their vehicle becomes buoyant and should be an area of further research.

This conference paper is a summary of the final report submitted to the BNHCRC. Please contact Haynes.kathatine@gmail.com for further details.

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