An analysis of the causes and circumstances of flood disaster deaths

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The objective of this paper is to investigate and to improve understanding of the causes and circumstances of flood disaster deaths. A standardised method of classifying flood deaths is proposed and the difficulties associated with comparing and assessing existing information on flood deaths are discussed. Thirteen flood cases from Europe and the United States, resulting in 247 flood disaster fatalities, were analysed and taken as indicative of flood disaster deaths. Approximately two-thirds of the deaths occurred through drowning. Thus, a substantial number of flood disaster fatalities are not related to drowning. Furthermore, males are highly vulnerable to dying in floods and unnecessary risk-taking behaviour contributes significantly to flood disaster deaths. Based on these results, recommendations are made to prevent loss of life in floods. To provide a more solid basis for the formulation of prevention strategies, better systematic recording of flood fatalities is suggested, especially those caused by different types of floods in all countries.

Keywords: disaster deaths, drowning, flood deaths, flood fatalities, flood mortality, flooding.

Introduction

Flood fatalities in context

During the twentieth century, floods killed at least eight million people (EM-DAT, 2004). Floods are often cited as being the most lethal of all natural disasters (Alexander, 1993; French and Holt, 1989), although numerous critiques of such statements are made (EM-DAT, 2004; Jonkman, 2005). This paper examines some of the issues raised by starting from basic definitions in order to identify, categorise, evaluate and understand how people die in floods. A contribution towards more consistent recording of natural disaster fatalities is made by focussing on individual fatalities in specific events.

Definitions

Due to the complex interrelated processes that can cause and influence floods, defining and classifying them is not simple. Proposing definitive, legalistic definitions of 'flood', 'flood disaster' or 'flood fatality' is not attempted here. Instead, working definitions are used:

- Flood—the presence of water in areas that are usually dry.

Disasters, 2005, 29(1): 75–97.
Published by Blackwell Publishing, 9600 Garsington Road, Oxford, OX4 2DQ, UK and 350 Main Street, Malden, MA 02148, USA

- Flood disaster—a flood that significantly disrupts or interferes with human and societal activity.
- Flood fatality or flood-related fatality—a fatality that would not have occurred without a specific flood event. Synonyms and related terms include 'flood deaths', 'loss of life in floods', 'flood mortality' and 'killed by flooding'.

These definitions are imperfect and exceptions exist. For example, dams and locks along a torrent may be affected by a flood, disrupting human and societal activity, yet without causing any inundation in areas that are usually dry.

The definition of flood fatality also raises questions regarding the timing of death. Kelman (2005) argues against labelling deaths as 'direct' or 'indirect', so this approach is not adopted here; however, some flood deaths are immediate (like those resulting from drowning) and others could be delayed (such as those due to psychological effects or disease). To address this issue and the possible separation between the flood disaster and the potentially associated death, the approach taken here emulates other work by dividing the flood disaster into three phases: pre-impact; impact; and post-impact. Nonetheless, inadequate data meant that long-term flood mortality could not be explored in the post-impact phase.

Despite the concerns and inconsistencies, these definitions provide a useful and necessary starting point for analysing flood fatalities.

Scope and objective

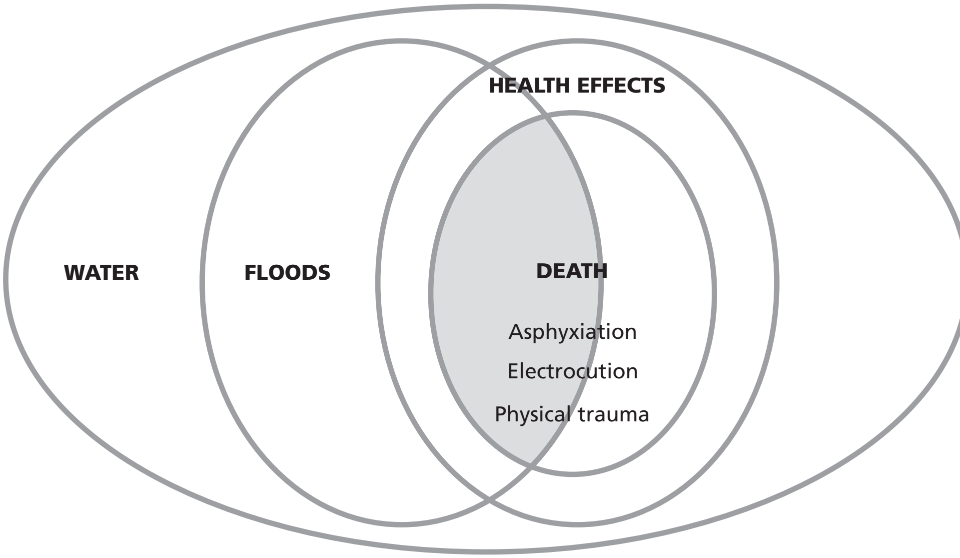
As figure 1 illustrates, floods are a subset of the effects of water on society. Water, floods and flood disasters have positive and negative ramifications for society, including economic, environmental, social, and health consequences. This paper focuses on negative health effects.

Health effects (on human beings) can be psychological (mental) or physiological (physical). One physical health effect associated with both water and flood disasters is death. Death might result from an array of medical causes, three examples of which are shown in figure 1—a more complete set is proposed below in the section entitled 'Analysing flood disaster deaths'. The shaded area represents the scope of this paper: flood deaths due to mainly physical causes.

Other health effects in figure 1 are important, but they have been well documented in the literature already. Non-lethal health effects of floods have a wide body of references for physical health effects (Marwick, 1997; Noji, 1993) and mental health effects (Price, 1978; Selten et al., 1999). Similarly, excellent work has been completed on all kinds of drowning, not just flood-related (Ahmed et al., 1999; Mackie, 1999), and on more general water safety (Gabe and Hite, 2003; LACOE, 1997).

In contrast, flood fatalities are rarely examined across several flood disasters to identify trends with respect to medical causes of deaths along with the vulnerabilities that led to those deaths. Many authors call for or propose uniform classification schemes for disaster deaths (Combs et al., 1999) and flood disaster casualties (Hajat et al., 2003; Legome et al., 1995; WHO, 2002). This paper aims to start filling this gap by approaching

Figure 1 Schematic diagram showing the effects of water on society, of which flood deaths are a subset



Notes The shaded area is investigated in this study. Three examples of death are given.

the problem systematically and by drawing on the literature that examines individual deaths due to specific flood events.

The objective of this paper is to investigate and to improve understanding of the causes and circumstances of flood disaster deaths. In this context, a systematic scheme for reporting flood disaster deaths is proposed. Based on the analysis, strategies can be formulated to prevent flood disaster deaths.

This paper focuses on Europe and the US due to the information available, but other locations are mentioned when appropriate sources exist. One unfortunate consequence is limited discussion on flood deaths in less developed countries, which is where most flood fatalities have occurred in the past (EM-DAT, 2004). Despite this paper's lack of focus on less developed countries, the results presented here should assist all nations.

The scope, objective and definitions have been set out. The next step is to review past work. Section three then proposes frameworks for analysing flood fatalities. Section four includes an assessment of flood deaths based on case studies. Finally, section five offers some conclusions and recommendations.

Previous studies

Health effects leading to death

The literature on flood disaster health effects that result in death rarely quantifies or classifies the causes and circumstances of death. Ohl and Tapsell (2000) state that, in the aftermath of a flood disaster, deaths and injuries not only result from the physical characteristics of the event but also are determined by the prevailing socioeconomic and health conditions of the community. Bennet (1970) investigated the longer-term effects of floods on mortality after the 1968 floods in Bristol, United Kingdom. For the 12 months after the flood event, he showed an increase in population mortality rates of 50 percent in the flooded part of the city compared with no appreciable change in mortality in the non-flooded part. Similar patterns in post-flood mortality were observed in Canvey Island, UK, after the 1953 flood disaster (Baxter et al., 2001) and on the Canary Islands, Spain, after the 1953 inundations (French and Holt, 1989).

Other studies do not report increases in post-flood mortality; for example, those that have looked at the 1988 flood disaster in Nîmes, France (Duclos et al., 1991) and the 1974 flood disaster in Brisbane, Australia (Abrahams et al., 1976). Overall, strong evidence persists regarding the connections between psychological health effects and mortality in flood disasters, but quantitative assessments are difficult due to the challenges of long-term data collection and attributing definitively a specific death to a particular cause long after an event.

Studies on flood disaster deaths

A few studies aggregate flood disaster deaths. Coates (1999), analysing Australian flood deaths between 1788 and 1996, highlighted the large number of fatalities that occurred as a result of people attempting to travel across floodwater, being caught in a campsite, being trapped inside a building or attempting to rescue someone else.

Data on flood disaster deaths in the US are presented by French et al. (1983) and Mooney (1983). Vehicle-related deaths were the dominant cause in both studies, constituting 42 percent (French et al., 1983) and 49 percent (Mooney, 1983) of all recorded fatalities. Significant numbers of fatalities also occurred in homes, on campsites, when crossing bridges or when walking through floodwaters. Coates (1999), French et al. (1983) and Mooney (1983) all highlight an overrepresentation of males in the death statistics. In addition, they point to increased vulnerability of young and elderly people.

These studies on aggregated flood disaster death data provide a first indication of vulnerability factors—namely age, gender and activity—which are important for analysing the causes of flood fatalities. These studies help in understanding the problem, but do not yet provide adequate explanations and categorisation for developing solutions.

Some literature is dedicated to estimating loss of life due to floods in the context of a safety assessment of flood protection systems, such as dams and dikes. Jonkman et al. (2002) provide an overview. These assessments, though, do not offer insight into the root causes and the mechanisms that determine loss of life due to floods. Human stability in flowing water is also examined by some authors (such as Abt et al., 1989), indicating that people lose their stability in relatively shallow depths and at relatively slow flow velocities.

Specific cases of fatal flood disasters

A third category of literature has emerged through the documentation of fatalities in specific flood disasters. The event-based data and the descriptions offered in these studies provide insight into the factors determining, and the causes of, loss of life in floods, which form the basis for the work presented here.

Appendix A summarises the cases (table A.1) and other literature (table A.2) utilised in this analysis. A total of 13 cases involving 247 flood disaster fatalities were analysed and taken as representative of the literature and as indicative of flood disaster deaths reported; however, this selection might not be representative of all flood disaster deaths. In particular, the cases are from only specific locations in Europe and the US. As discussed later, biases related to the event typology and the culture of these locations could influence the results and caution is warranted in interpreting the conclusions provided here more generally.

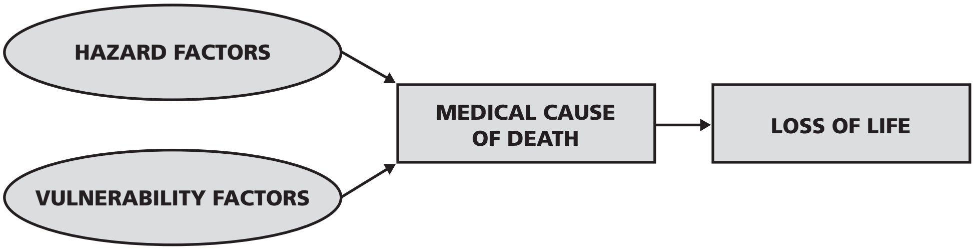
Possible case studies were limited because they had to provide adequate data on the age and gender of each individual victim, timing of death, medical cause of death, and activity or circumstances. For consistency, each case study is relatively recent (within the past 20 years) and involved relatively few deaths (less than 50). The individual-by-individual data were then aggregated for analysis. To prevent loss of information on typical event patterns or individual characteristics, the available information was investigated (see the section entitled 'Results and discussion' below) on different levels: aggregated, event and individual fatality level. Other events are used for comparison when appropriate.

Analysing flood disaster deaths

Framework proposal: overview of factors

A combination of hazard factors and vulnerability factors result in a flood death due to a specific medical cause (figure 2). For example, an ill girl (vulnerability) could lose her stability in floodwater imparting a certain hydraulic load (hazard) on her resulting in her drowning or dying as a consequence of physical trauma (medical cause of death). Similarly, rising floodwater (hazard) could lead to the evacuation of a retirement home in the flood plain (vulnerability) and two residents having heart attacks (medical cause of death). Therefore, medical causes of death are not vulnerability factors in themselves but are the product of the amalgamation of hazard and vulnerability elements.

Figure 2 Hazard and vulnerability factors that result in loss of life due to a specific medical cause



To determine the effects of flood hazards on people, they could be interpreted as 'flood actions' (see Kelman and Spence, 2004); that is, how the flood acts on individuals. Flood actions include forces, pressures, motion, oxygen deprivation, chemical reaction due to contaminants, debris impacts and flood-related fire consequences. Flood hazard variables used to calculate flood actions include water depth, water depth rise rate, water velocity, wave characteristics, water temperature, and the amount and the nature of debris and contaminants. Studies on flood deaths rarely provide adequate quantitative data on flood actions.

Vulnerabilities of an individual potentially leading to death in a flood disaster include age, gender, physical and mental health history, current physical and mental condition, activity and behaviour (such as attempting a rescue, sleeping or evacuating), clothing worn, swimming ability and experience (likely only to be relevant for non-moving water), temporary impairment (for instance, due to alcohol or drugs), knowledge of the area where the flood is occurring, situation/place (for example, on foot, on a bicycle, in a vehicle or in a building), and rescue (including self-rescue) and medical response capabilities. As shown in Appendix A, age and gender are usually reported in the flood disaster death literature. Other vulnerability factors considered occasionally are impairment and timing. Appendix A further illustrates that medical causes of flood disaster deaths are usually listed, which are then often misinterpreted as being the fundamental cause of death. In the existing literature, though, links between the flood actions (that is, hazard factors), individual vulnerabilities and medical causes of death are rarely made. This paper strives to achieve more in this realm through the classification method chosen.

Developing a classification method for flood disaster deaths

Consistency problems emerge when trying to define a flood death because a disaster event might involve numerous different phenomena, leading to deaths from different causes. The disaster might also appear to be of a different type than the phenomenon that causes most fatalities. For example, two events in the US, Hurricane Floyd in 1999 and Tropical Storm Allison in 2001, are classified by EM-DAT (2004) as windstorms, even though the majority of fatalities was the result of drowning in inland waterways (MMWR, 2000; NOAA, 2001). The 1991 Bangladesh cyclone is also classified as a windstorm by EM-DAT (2004), yet most of the 139,000 fatalities were the result of drowning due to storm surge flooding (Haque and Blair, 1992; Chowdhury et al., 1993). The floods in the UK in autumn 2000 (Kelman, 2001) are another ambiguous example, since they resulted from several storm systems. Deaths were both wind-related, such as falling overboard in choppy seas or being crushed by trees, and flood-related, such as drowning in flooded rivers.

This paper relies on the definitions set out in the introduction. Deaths are flood-related only if they occurred during an event involving the presence of water on land that is usually dry. Thus, drownings and heart attacks during floodwater-induced evacuations are flood disaster-related deaths, whereas people being blown off ships or off the road (by wind) generally are not.

Further ambiguities emerge that make rigid application of this approach challenging. Tropical cyclones tend to cause blackouts that lead to death from electrocution during grid repairs, carbon monoxide poisoning due to improper use of personal generators, and candle-induced fires. Normally, high winds are responsible for the blackouts, but flood actions can also cause power outages. Classifying electricity-related deaths as wind-related or flood-related is not straightforward.

Rather than debating the classification of each individual death, a decision was taken to catalogue each event as flood or non-flood based on the origin and extent of deaths and damage and the resultant societal perception. Thus, despite ambiguities, the autumn 2000 floods in the UK and Tropical Storm Allison in the US in 2001 are considered to be flood disasters, whereas Hurricanes Marilyn and Opal in 1995 (MMWR, 1996) in the US are not. Some decisions could be contentious; the cases are listed in Appendix A to permit discussion.

An important point to underline is that the flood disasters appraised constitute only a selection, they are not comprehensive. Hence, excluding a flood disaster would have less impact on the results than including a non-flood disaster. Irrespective, since drowning naturally tends to indicate a flood event, a difficult-to-classify event involving few instances of drowning would likely be excluded. Consequently, drownings might be overrepresented in the fatality statistics.

This approach is challenging to implement consistently, particularly in light of inconsistent data, ambiguous definitions, and differences among references for particular events and specific fatalities. Therefore, the results here can be considered to be only first-order, giving informative and practical insight into flood disaster deaths.

Classification method for flood disaster deaths

No generally accepted classification method for flood fatalities exists. Different classifications with varying levels of detail for reporting flood-related deaths are found in the literature, which are often poorly described or weakly documented. Consistency problems might thus manifest themselves when comparing different flood disasters.

Hence, the interpretations in this study could reflect the choices made in previous studies and the biases resulting from these choices. To attempt to minimise such biases here, non-aggregated, raw data have been utilised as much as possible. Additionally, long-term flood mortality is not explored. Instead, deaths that occurred just before, during and shortly after flood events are considered. Despite potentially debatable judgements, the advantages of this approach include the opportunities:

- to compare different events and to examine simultaneously flood disaster deaths in many flood disasters;
- to develop a proposal for standardised data collection that factors in key vulnerabilities leading to flood disaster deaths; and
- to establish a relatively solid basis for mitigation and education.

Based on the literature review, a classification is proposed in table 1. Each category is generally self-explanatory, but some notes are provided below.

Table 1 Classification of flood disaster deaths

Medical cause	Activity	Timing	Gender	Age	Lack of judgement[1]
Drowning	As a pedestrian	Pre-impact phase	Female	0–19 years	Yes
	In a vehicle	Impact phase	Male	20–59 years	No
	From a boat	Post-impact phase	Not reported	Older than 60 years	
	During a rescue attempt	Not determinable		Not reported	
	In a building				
Physical trauma	In water				
	As a pedestrian				
	In a vehicle				
	On a boat				
	During a rescue attempt				
	In a building				
Heart attack					
Electrocution					
Carbon monoxide poisoning					
Fire					
Other					
Unknown or not reported					

Notes

1. If not enough information is available to record a definite 'yes', then 'no' is recorded.

Each fatality in each event was given one classification in each column. That is, one medical cause and activity classification, one timing classification, one gender classification, one age classification, and a decision on whether or not lack of judgement by that individual or someone else was unambiguously to blame.

The category 'other' should be expanded when needed. For example, if many fatalities occurred due to snake bites, trampling by hippopotamuses, jellyfish stings, water-related disease due to the flood, or other factors, then they should be listed explicitly. Similarly, 'cold water shock', where the heart stops due to the shock of being immersed in cold water, is occasionally suggested (and disputed) as a cause of death rather than drowning. Expanding the 'other' category might also be useful for recording further details, if available, such as the highly specific categories used by McClelland et al. (1999), and for identifying event sequences that cause flood-related mortality. During a 1991 flood in Texas, a fatality in a non-flooded mobile home resulted from fire ants being flushed out of the ground by the flood, which subsequently invaded the victim's house and caused a short circuit in the electrical wiring that started a fire that killed the occupant (Brenner et al., 1994).

The World Congress on Drowning (WCD) (2003) has adopted the following as a definition of drowning: 'the process of experiencing respiratory impairment from submersion/immersion in liquid'. According to Bierens (1996), both hypothermia and asphyxiation occur during the drowning process, yet the former might cause the victim to lose strength and thereby to drown. Either hypothermia or drowning/asphyxiation could be selected to classify such deaths, but the literature tends to categorise them as drownings. Thus, deaths from exposure, hypothermia or cold (in floods) are not accorded separate categories in this study, and only one death in the case studies was explicitly labelled as such.

Physical trauma includes people being killed as a result of being hit by debris in the water, the collapse of a building due to the flood or vehicle crashes influenced by floodwater.

The categories are not absolute. For instance, physical trauma that causes unconsciousness could lead to either drowning or hypothermia. The classification results will thus to some extent reflect the analyst's judgments and the information available.

Results and discussion: factors influencing flood disaster deaths

Cause of death and circumstances

For the 13 studied flood cases the aggregated data on medical cause of death and the surrounding circumstances are shown in table 2.

Drowning accounts for the majority of the fatalities (67.6 percent), with the implication for education and mitigation that approximately one-third of flood disaster fatalities are not due to drowning. Vehicle-related drowning occurs most frequently, mainly when people try to drive across flooded bridges, roads or streams. Such instances of drowning occur during several phases of the flood: at the onset, when people are surprised by the floodwaters, and in the aftermath, such as after the storm system has passed but when the waters are still high.

Low-water crossings, where a road traverses a normally dry stream bed or where there is a slight dip in the road across a drainage area, are particularly dangerous (Kelman, 2005). This may reflect motorists' misconception that automobiles can provide adequate protection from rising water (MMWR, 1993). Another especially dangerous activity is driving over flooded bridges. In the 1992 Puerto Rico floods, 11 of the 14 fatal car crashes happened on a flooded bridge (Staes et al., 1994).

Specific dangers are associated with attempted rescues, but the consequences vary. As can be seen in table 2, three people lost their lives during the rescue process, only one of whom was a rescuer. Other sources, not included in the data in table 2, confirm the dangers associated with rescue. In North Carolina, when Hurricane Floyd hit in 1999, five rescuer deaths were reported in a death toll of 52 (MMWR, 2000). In the 1988 floods in Nîmes, France, two of the nine people who lost their lives drowned during rescue operations (Duclos et al., 1991).

Table 2 Distribution of the causes and circumstances of death for the 13 events listed in Appendix A

Cause of death and the surrounding circumstances		Total deaths	Total deaths (%)	Aggregates
Drowning	As a pedestrian	62	25.1	All drownings 167 (67.6%)
	In a vehicle	81	32.8	
	From a boat	7	2.8	
	During a rescue attempt	2	0.8	
	In a building	15	6.1	
Physical trauma	In water	0	0	All physical trauma 29 (11.7%)
	As a pedestrian	4	1.6	
	In a vehicle	14	5.7	
	On a boat	2	0.8	
	During a rescue attempt	1	0.4	
	In a building	8	3.2	
Heart attack		14	5.7	
Electrocution		7	2.8	
Carbon monoxide poisoning		2	0.8	
Fire		9	3.6	
Other		3	1.2	
Unknown or not reported		16	6.5	
Total		**247**	**100**	

Fourteen (5.7 percent) heart attack fatalities were reported, three of which occurred during the evacuation process following the 2002 floods in Germany. Better preparation and planning, which would eliminate the need for sudden and stressful evacuations, could save lives (Kelman, 2005).

All deaths due to fire and carbon monoxide poisoning happened in buildings. Also in buildings, 15 (6.1 percent) fatalities were the result of drowning and eight (3.2 percent) were due to physical trauma. In most events, people living in the affected areas could be warned and evacuated, but those actions—and preparation for those actions—must be effected properly (Handmer, 2000). In addition, the consequences of evacuation must be less than the consequences of non-evacuation.

Differences between flood deaths in Europe and the US, as shown in table 2, are of particular interest. The most striking difference to emerge is that drowning in vehicles seems to be a worse problem in the US than in Europe. Possible reasons for this are:

Europe deaths	Europe deaths (%)	Aggregates	US deaths	US deaths (%)	Aggregates
34	35.8	All drownings 65 (68.4%)	28	18.4	All drownings 102 (67.1%)
12	12.6		69	45.4	
6	6.3		1	0.7	
2	2.1		0	0	
11	11.6		4	2.6	
0	0	All physical trauma 14 (14.8%)	0	0	All physical trauma 15 (9.8%)
0	0		4	2.6	
9	9.5		5	3.3	
2	2.1		0	0	
1	1.1		0	0	
2	2.1		6	3.9	
7	7.4		7	4.6	
0	0		7	4.6	
1	1.1		1	0.7	
0	0		9	5.9	
3	3.2		0	0	
5	5.3		11	7.2	
95	100		152	100	

- a better understanding or stronger recollection of the dangers of flooding in Europe;
- better warning systems combined with better compliance with warnings in Europe;
- different nature of flooding in Europe and the US;
- higher recurrence rates of floods that pose a danger to vehicles in the US, perhaps due to differing road networks (for instance, fewer low-water crossings in Europe) or different flood characteristics (for example, intensity of cloudbursts); and
- different reporting systems for flood deaths.

Similarly, all reported deaths due to electrocution and fire occurred in the US. A different system of reporting data or different terminology could be reasons. Such differences would be difficult to trace back without reconstructing the circumstances surrounding each fatality.

Furthermore, the types of events considered might influence the outcomes. Most US events analysed were associated with windstorms (that is, cyclones), while the European floods comprised mostly river floods. Inclusion of the 1999 floods in France would have reduced the difference between the US and Europe with regard to car-related drownings, as ten of the 24 fatalities in the former event were the result of drowning in vehicles (ICPR, 2002). This event was not included here because the International Commission for the Protection of the Rhine (ICPR) (2002) did not provide data on individual fatalities. Due to the limited sample of case studies considered and the lack of a standardised reporting scheme, no definitive conclusions on differences between locations could be reached. The France 1999 example underscores that the small dataset considered here leads to potentially unreliable conclusions.

Age

Three age bands were used to examine vulnerability due to being old or young, as reported by Mooney (1983) and Coates (1999). For example, Mooney found that 55 percent of those who lost their lives in flash floods in the US were under the age of 21.

From table 3, the increased vulnerability of the young and elderly cannot be confirmed; however, indications are that, as expected, some age groups might be more vulnerable to certain causes of death. Of the 33 people who died who were under 20 and for whom the cause of death was identified, 15 drowned in vehicles, in most cases as a passenger, seven died as pedestrians, five died in a single fire, three died due to physical trauma, two died while boating and one drowned in a building. Seventy-nine percent of the people under 20 who died lost their lives in floods in the US—by contrast, 60 percent of the deaths in the case studies occurred in the US—indicating higher vulnerability among young people to floods in the US than in Europe.

The increased vulnerability of the elderly to heart attacks is confirmed to some extent by the fact that five of the deaths due to a heart attack that occurred during the 2002 floods in Germany involved people over the age of 65 (Reimer, 2002). However, age is not reported for the eight other heart attack deaths in the case studies examined here.

With regard to European flood fatalities, 25.3 percent of the people who lost their lives were over the age of 60, compared with 11.2 percent in the US. Several factors

Table 3 Distribution of flood fatalities according to age

Age band	Total	Total (%)	In Europe	In Europe (%)	In US	In US (%)
0–19 years	33	13.4	8	8.4	25	16.4
20–60 years	98	39.7	47	49.5	51	33.6
> 60 years	41	16.6	24	25.3	17	11.2
Not reported	75	30.4	16	16.8	59	38.8
Total	**247**	**100**	**95**	**100**	**152**	**100**

might influence these statistics. In the US, non-elderly people might take risks in floods that their European counterparts do not. In Europe, the elderly might be left to fend for themselves during floods more frequently than in the US; they might choose to stay in flooded buildings; or they might experience difficulties in receiving, interpreting and acting on flood warnings. The ICPR (2002) notes that, during the 1999 floods in France, eight of the nine drownings in buildings involved 'pensioners'. In the cases examined here, one-half of the drownings in buildings involved elderly people, suggesting that this factor could be important.

Gender

Table 4 shows the distribution of flood fatalities according to gender. Of the fatalities where gender is reported, 70 percent are male. For all flood events examined here, the number of male deaths exceeds (11 cases) or equals (two cases) the number of female deaths. One hundred and eighty-four fatalities report both individual cause of death and gender. Males are significantly overrepresented in vehicle crashes, drowning and physical trauma, and in cases of pedestrian drowning. Likely contributing factors are the large number of males who drive, the high proportion of males who work for the emergency and supporting services, and the risk-taking behaviour of males (discussed further below). For other causes of death, no apparent differences between males and females are evident. Furthermore, the relationship between gender, cause of death and age category has been checked, showing that males are overrepresented in all three age categories.

Activity and behaviour

The way in which people respond to floods is an important factor in the associated morbidity and mortality (French and Holt, 1989). A substantial proportion of the flood-related deaths is believed to be attributable to unnecessary risk-taking behaviour.

The 2002 floods in Germany illustrate the preventable nature of such deaths. Reimer's (2002) descriptions of the circumstances surrounding individual deaths suggests that at least eight of the 19 fatalities were due to unnecessary action:

Table 4 Distribution of flood fatalities according to gender

Gender	Number	Percent	In Europe	In Europe (%)	In US	In US (%)
Male	145	58.7	72	75.8	73	48.0
Female	62	25.1	22	23.2	40	26.3
Not reported	40	16.2	1	1.1	39	25.7
Total	**247**	**100**	**95**	**100**	**152**	**100**

- six people entered their home or the floodwaters to rescue belongings, such as laundry or firewood;
- one person was boating in the floodwaters; and
- one person tried to drive across a flooded street.

Other reported examples of risk-taking behaviour in floods include driving around barricades warning of the danger and attempting to wade across flooded watercourses. During several recent European floods, different forms of flood tourism were reported, including large crowds gathering on riverbanks and bridges and people engaging in recreational boating activities on flooded streams.

Similar observations with respect to the contribution of risky behaviour to Australian flood deaths are provided by Coates (1999). The Australian figures show that 8.3 percent of the fatalities occurred when victims attempted to retrieve stock or property and that 5.7 percent of the fatalities resulted from persons undertaking recreational activities in the flooded area. The World Health Organization (WHO) (2002) estimates that 40 percent of all health impacts in European floods are related to risk-taking behaviour. The ICPR (2002) notes that, in Switzerland, 40 percent of the 67 flood fatalities that occurred between 1972 and 2001 were due to what it terms 'misconduct'. Sometimes, unnecessary risky behaviour might lead to the death of another person, such as a passenger in a vehicle.

Timing of death

Timing of death relative to flood occurrence has been deduced for 214 fatalities (see table 5). Of these 214 fatalities, 87 percent occurred during the impact phase. Nonetheless, a bias in the data is likely in terms of excluding pre-impact and many post-impact fatalities while including most impact phase deaths (Duclos and Isaacson, 1987). For example, Water Safety New Zealand maintains a database of cases of drowning in New Zealand but does not consider post-impact flood-related drownings to be associated

Table 5 Distribution of flood fatalities according to timing of death

Timing	Number	Percent	In Europe	In Europe (%)	In US	In US (%)
Pre-impact phase	0	0	0	0	0	0
Impact phase	187	75.7	83	87.4	104	68.4
Post-impact phase	27	10.9	4	4.2	23	15.1
Not determinable	33	13.4	8	8.4	25	16.4
Total	**247**	**100**	**95**	**100**	**152**	**100**

with the flood event. Deaths that are reported in the post-impact phase of the case studies examined here were mainly related to clean-up operations and include heart attacks and vehicle-related drownings.

The relationship between time of death and the issuance of official warnings could not be investigated here due to lack of information. Staes et al. (1994) examines this issue with respect to the 1992 Puerto Rico floods: three of the 23 deaths happened before flash-flood watches were issued, while 17 deaths occurred before flash-flood warnings were issued.

Similarly, at what point in the day death occurred could not be fully analysed, but the available evidence suggests little pattern. In the 1997 Poland floods, all deaths occurred during the day (M. Mierkiewicz, personal communication). For the 1992 Puerto Rico floods, all deaths occurred during the evening (Staes et al., 1994).

Mooney (1983) shows that nearly 75 percent of flash-flood deaths in the US occurred during the hours of twilight and darkness. This high percentage might be due to the unexpected character of flash floods and their rapid onset, compounded by darkness. Similar suggestions have been made for the 1953 North Sea storm surge in England and the Netherlands (Grieve, 1959). This phenomenon might be less relevant for other types of floods.

Season is also pertinent to flood fatalities. Enough data—mainly related to air and water temperature—were not available to determine whether or not the mortality rate was higher during certain seasons. Additionally, other seasonal factors, such as the number of hours of darkness per day, might influence the number of deaths.

Other factors

Some studies highlight other factors relating to flood deaths, such as blood alcohol content and ethnicity (Thorne and Ararat, 2002). Such data are useful for this analysis, but did not appear in enough case studies to permit extensive comparisons to be made.

For the 1992 Puerto Rico floods (Staes et al., 1994), blood alcohol content was measured with respect to 16 adult deaths: 12 had some alcohol in their blood, including five who had levels greater than 0.1 percent. The flood event happened during a public holiday, presumably contributing to the inebriation of the victims. Thorne and Ararat (2002) show that 17 of the 23 fatalities in the area of Houston, Texas, during the 2001 Tropical Storm Allison floods had positive blood alcohol levels. In these cases, the flood deaths point to an alcohol problem more than a drowning or flood fatality problem. Given these results, a connection between drunk driving and vehicle-related flood deaths should be investigated.

Thorne and Ararat (2002) also report that 20 of the 23 people who lost their lives belonged to certain ethnic (black and Hispanic) groups. Based on their limited evidence and lack of information about the ethnic breakdown of the wider population, no definitive conclusions on the relevance of ethnicity could be drawn.

In the section above entitled 'Framework proposal', (potentially) relevant individual vulnerability factors were outlined. The available dataset did not contain information on more specific individual conditions of the people who died, such as physical and mental state, swimming ability, clothing worn and knowledge of the area. Similarly, little information was provided on the flood actions and hazard variables, such as the hydraulic conditions, the water temperature and the degree and nature of any water contamination. The analysis of causes of death, illustrating the perils of driving or walking through floodwater, demonstrates the relevance of hazard factors in fully understanding flood fatalities. Furthermore, no data were found on the effectiveness of rescue operations and medical interventions.

Further discussion

The previous sections have mainly focussed on the influence of individual vulnerability factors. Cross-checking analyses suggest that complex patterns among vulnerability factors might exist. In some cases, they might be logical, such as the increased vulnerability of the elderly to heart attacks. More complicated patterns—including interrelations between cause of death, gender, ethnicity and alcohol abuse—might exist, but they could not be examined without more data.

Preparation, warning and evacuation have a role to play in preventing flood fatalities. The most lethal flood disasters, particularly flash floods and storm surges, appear to hit with little warning and are of such a large scale that ad hoc escape is challenging. Two examples are the 1953 North Sea storm surge (over 2,300 fatalities) and the 1991 Bangladesh cyclone (approximately 139,000 fatalities). These higher fatality events might exhibit different mortality patterns to the smaller-scale events studied here.

In contrast to the overrepresentation of male deaths found here, the 1953 floods in the Netherlands resulted in nearly equal distribution of fatalities between the genders (Jonkman et al., 2003; Kelman, 2003). In the 1991 Bangladesh cyclone, death rates were substantially higher for females than for males (Chowdhury et al., 1993). Possible reasons indicated for women's vulnerability are the social role of women, their style of clothing, their lower physical ability and their level of nutrition. Similarly, while only a few of the fatalities in this study occurred in buildings, a significant number of the 1,835 fatalities in the Netherlands during the 1953 storm surge were due to the collapse of buildings (Slager, 1992).

The transferability of the results of this study to other regions could be questioned, but transferring the methodology is recommended. Apart from the flood characteristics, socio-economic factors could play an important role. The latter include the potential to warn of, to respond to, and to cope with, a flood disaster. In Bangladesh, for instance, 600,000 people live on river islands called chars which are vulnerable to erosion and flooding (Sarker et al., 2003). Livelihood interests, such as the availability of fertile soil and the lack of space and opportunity elsewhere, lead—or force—people to live there despite the flood risk. The conclusions of this study might apply to only the floods examined: that is, smaller-scale floods in Europe and the US.

On a global scale, a comparison of average flood event mortality (number of fatalities divided by number of affected persons) with other types of disasters is provided in (Jonkman, 2005). Average flood mortality for slow-onset floods, such as drainage and river floods, is relatively low (in the order of 0.01–0.5 percent). More rapid floods, such as flash floods (average mortality equals 3.6 percent), tend to have death rates of the same order of magnitude as an average earthquake (3.1 percent) or windstorm (2.6 percent). The relatively high average mortalities for events that occur with little or no notice indicates the importance of suitable warnings, and acting appropriately to warnings, for saving lives. This is also believed to be valid for other types of disasters. With regard to landslides, for example, Guzzetti (2000) and Alexander (2004) show that fast-moving failures were responsible for more than 80 percent of deaths and injuries, while slow-moving landslides rarely resulted in casualties.

Conclusions and recommendations

Conclusions

The objective of this paper is to investigate and improve understanding of the causes and circumstances of flood disaster deaths. By analysing data on 247 deaths in 13 floods, the reasons for these flood fatalities have been examined.

One of the main difficulties in collecting and appraising data relates to defining a flood death. Different forms of data are published and different classifications are used. The published data are limited, covering only part of the information needed to determine the full cause of death. To start overcoming these issues, a set of working definitions along with a standardised method of classification for flood disaster deaths have been proposed.

Despite the limitations discussed, this study provides a representative analysis of flood deaths for relatively small-scale floods in Europe and the US. The analysed data illustrated that:

- approximately two-thirds of the analysed flood deaths were due to drowning. An important implication of this is that a substantial proportion of the fatalities is due to causes other than drowning, such as physical trauma, heart attack, fire, carbon monoxide poisoning and electrocution;
- 70 percent of flood deaths involve males, suggesting high flood vulnerability among that gender;
- in contrast to previous studies, enough evidence was not available to draw conclusions on age-related vulnerability;
- the response of people and their actions are critical and should be examined in closer detail. Significant numbers of flood deaths are attributable to unnecessary risky behaviour; and
- in the two cases where the alcohol blood levels of the victims were measured, the majority of the victims had positive alcohol blood levels.

Nonetheless, the available data have many weaknesses and there is scope for much more work, particularly in terms of collecting comprehensive, standardised information. If this could be done, the result could lead to policies and actions that reduce the number of flood disaster deaths.

Recommendations

Systematic data collection

This study has highlighted many difficulties associated with identifying, defining and classifying flood disaster deaths. A set of working definitions has been proposed, and table 1 could be used as a first-order standardised 'fact sheet' for future data collection. Decisions to include or exclude data should strike a balance between data collectability and importance.

Potentially important vulnerability data are blood alcohol content, swimming ability and factors related to receipt of, and compliance with, warnings. The influence of hazard characteristics is poorly documented in the existing literature. Potentially important hazard data would relate to flood actions (Kelman and Spence, 2004) or more generally to flood type (Jonkman, 2005).

Such systematic recording and tracking of flood fatalities would allow policy and practice to be based on fundamental data. Insight gleaned from vulnerability characteristics could be used to target education, awareness and warning programmes at the sub-populations that display a persistent tendency to be killed by floods. Improved understanding of the relationship between hazard and vulnerability factors and potential loss of life in floods would also provide a better basis for loss of life estimation and for evaluating possible mitigation strategies.

These data should be collected for all areas of the world and for all types of floods. Following previous recommendations (WHO, 2002; Hajat et al., 2003) the 'fact sheet' could eventually be expanded into a broader system for reporting flood morbidity and mortality, including the non-lethal health effects and longer-term mortality connected with flood disasters.

A private, international foundation might be the most suitable choice for implementing and maintaining this scheme, while emulating the approach of EM-DAT (2004) to making the data available. We estimate that the research and application benefits of systematic data collection for the prevention of flood fatalities would far exceed the costs.

Preventing loss of life

In general, education, awareness and warning appear to be key to preventing flood mortality. For example, people should avoid entering floodwaters, either by vehicle or on foot, and other risk-taking activities, generally associated with males, should be curtailed. The issues pertain to all phases of the flood: before the water rises, during the event, and especially after the storm system has passed but water levels remain high and dangerous. Deaths due to causes other than drowning should also be specifically targeted for reduction, in particular heart attacks and post-impact fatalities. However, more evidence is needed to identify the underlying causes of death and the vulnerabilities.

Nonetheless, lack of adequate data is not an appropriate excuse for lack of action to prevent flood fatalities. Anecdotal lessons have emerged, reiterating comments and suggestions made by the likes of the Los Angeles County Office of Education (LACOE) (1997) and Thorne and Ararat (2002):

- do not walk through, drive through or otherwise enter floodwater;
- do not drink and drown; and
- replacing possessions costs less than drowning.

Acknowledgements

The authors would like to express their gratitude to Herman van der Most and Megan Morys for the comments that they provided on an earlier draft. Two anonymous referees are thanked for the useful comments that they supplied on the submitted manuscript.

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Appendix A
Specific cases of flood disaster deaths examined

Table A.1 Cases used to analyse flood disaster deaths

Location	Date	Event	Fatalities with data	Sources	Data reported or inferred for most fatalities				
					Age	Gender	Timing of death	Activity	Medical cause of death
Czech Republic (Moldau, Elbe)	9–11 August 2002	River floods	17	M. Veverka, personal communication	Exact	Yes	Yes	Yes	Yes
France (Rhône Valley, Lyon, Marseille)	1–5 December 2003	Storms and river floods	11	Media reports	Exact	Yes	Yes	Yes	
Germany (Elbe/Dresden)	11–20 August 2002	River floods	19	Reimer, 2002	Exact	Yes	Yes	Yes	Yes
Poland (Opolskie and Małopolskie provinces)	4–28 July 1997	River floods	14	M. Mierkiewicz, personal communication	Exact	Yes	Yes	Some	Yes
Poland (Wisla, Malopolskie and Swietokrzyskie provinces)	9 July–mid-August 2001	River floods	15	M. Mierkiewicz, personal communication	Exact	Yes	Yes	Some	Yes
UK (England)	9–15 April 1998	Storms and river floods	5	Media reports	Exact	Yes	Yes	Yes	Yes
UK (England and Wales)	Autumn 2000	Storms and river floods	14	Media reports	Exact	Yes	Yes	Yes	
USA (northeast)	10–13 December 1992	Nor'easter storm	4	MMWR, 1993	Exact	Yes	Yes	Yes	Yes
US (southeast)	4–14 July 1994	Tropical Storm Alberto	33	MMWR, 1994 NWS, c. 1994	Exact	Yes	Yes	Yes	Yes

US (northeast)	18–20 January 1996	Storms and river floods	33	NWS, c. 1996	Exact	Yes	Yes	Yes	Yes
US (south)	5–18 June 2001	Tropical Storm Allison	24	NOAA, 2001 Thorne et al., 2002	Exact	Yes	Yes	Yes	Yes
US (Puerto Rico)	5 January 1992	Storms and flash floods	23	Staes et al., 1994	Three ranges	Yes	Yes	Yes	Yes
US (South Carolina)	21 September 1989	Hurricane Georges	35	MMWR, 1989	A few	A few	Yes	Yes	Yes

Table A.2 Examples of other cases considered

Location	Date	Event	Fatalities with data	Number of considered events	Sources	Data reported or inferred for most fatalities				
						Age	Gender	Timing of death	Activity	Medical cause of death
Australia	1788–1996	All floods	2,213	926	Coates, 1999	Five-year intervals	No	No	Yes	No
Bangladesh	1991	Cyclone Brendan	1,206	1	Chowdhury et al., 1993	Five-year intervals	No	No	Some	Some
US	1969–1981	Flash floods	1,185	32	French et al., 1983	No	No	No	Yes/some	Yes
US	1977–1981	Flash floods	582	218	Mooney, 1983	Three ranges	No	No	Yes	No