Flood and Extreme Weather
Fatalities in the UK:
Exploring Vulnerability and Context

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Abstract

This thesis seeks to contribute to the body of knowledge about the most significant impacts of natural hazards – loss of human lives. There is a lack of research addressing deaths in less extreme, but still significant, events, such as surface water flooding in the UK, where there is no comprehensive list describing who died, where, how, and – crucially – why. Protecting lives and livelihoods is a key objective for flood risk management in the UK, but it is not clear which lives need protecting and from which risks.

To address this knowledge gap this project compiled, for the first time, a comprehensive list of flood casualties, as well as deaths from other extreme weather events in the UK, for the 15 year period 2000 – 2014. Newspaper reports were used as source data, using the LexisNexis® database of UK publications to select newspaper reports on flood and extreme weather casualties. Fatalities are rare enough and extreme enough to warrant a detailed and abundant interest from the media; these stories become a very rich source of data.

The compiled fatality dataset improves upon all other sources of hazard impact data, even though overall hazard fatality totals and rates in the UK are very low. A meteorological time series compares rainfall intensity at the time of flood fatality to show that lower hazard magnitudes also lead to fatal outcomes. Some trends in the geographical distribution of flood fatalities is identified, although no rural-urban or population density relationship is found. The most telling explanations of fatality trends arise from examining gender, age, and activity or behaviour at the time of death in severe weather. Further insights are drawn from exploring flood and extreme weather warning systems in the UK in terms of their effectiveness in predicting events which caused fatalities.

The low number of fatalities from weather hazards in the UK is a testament to the success of risk mitigation and reduction policies. However, many of the residual fatal impacts could have also been avoided. There are several compounding variables which cause the low but significant number of flood and extreme weather fatalities in the UK. One which stands out is the behavioural dimension of vulnerability, evident in the victims’ response at the time of the hazard impact. Conclusions are drawn for risk conceptualisation, vulnerability theory, extreme weather warnings, and potential communication strategies, which may have policy implications.
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Chapter 1 Introduction

In the last days of 2013, most of Great Britain was hit by a series of low pressure Atlantic weather systems in very quick succession. Winds of 60 to 80 mph lashed parts of the west coast. Ground saturated by rains gave way to flooding across western regions, and the Severn, the Thames and the Ouse all burst their banks. This was the start of a torturous winter, which would see severe floods engulf vast stretches of Somerset, Dorset, Cumbria, Oxfordshire, North Wales, Scotland and elsewhere. Power cuts and rail disruption effectively cut off parts of South West England from the rest of the country. The iconic pictures of the inundated Somerset Levels would dominate the broadcast and print media until March 2014. The costs of the floods of that winter have been estimated at £1.3 billion (Chatterton et al., 2016), but what of the human costs?

On Christmas Eve 2013 Nick Mutton, a 46-year-old school teacher from Newton Abbot in Devon was coming back from a last-minute trip to Asda with his 10-year-old stepdaughter and his labrador along the bank of the River Lemon. It had been raining intensely and the water table was high; the river was rushing rapidly and had risen considerably. Severe weather warnings had been issued by the MetOffice assessing risk of extreme rainfall impacts as yellow for most parts of the west and Scotland, with isolated areas of amber level precautions.

Seeing his dog struggle to get out of the water, Nick Mutton went to its rescue. Descending the bank, he slipped and fell into the swollen river. Although he was strong and tall, he couldn’t fight the strength of the current and the freezing temperature of the water. His stepdaughter could only watch as he was swept away. Although the emergency services managed to retrieve him, he died from the hypothermia. The labrador managed to escape.

Overall, five people died in the floods of those winter months. Remarkably, one in Cumbria, was under almost identical circumstances, when two days later the body of a 48-year-old man was retrieved from the River Rothay in Cumbria. He had been out walking a dog. A 39-year-old woman in Bangor, north Wales, drowned in a flooded stream as she tried to fix her water supply. Other victims included a 47-year-old man on a mobility scooter crossing a flooded path, a seven-year-old boy who died from inhaling flood pump fumes in his home, and a 68-year-old woman crushed by a flood-triggered landslide that tore through her home as she slept. Other weather impacts, such as storms and gales cased a further 12 fatalities during that difficult winter.
The weather impacts of the winter months were severe, and like nothing Great Britain had seen for many years. The floods of 2007, which cause more than £3.2 billion in direct damages (Chatterton et al., 2010), were even more costly but not so prolonged. The casualty toll of the events was also the most significant for a generation, if considered as a single event series. They were tragic accidents, which caught public and media attention, and became symbolic of the impact of the floods.

Yet we know surprisingly little about the scale of flood mortality in the UK, its underlying causes or trends over time. After major flood events, the Government often commissions ad hoc economic analyses (e.g. Chatterton et al. 2010; 2016), but there is no systematic assessment of the death toll. Could the death of Nick Mutton have been predicted by the intersection of weather forecasts and social factors? Was it particularly expected, given his background – would an emergency system have considered him to be at risk from such an accident? And therefore, could the incident have been forewarned and ultimately avoided? While these are the kind of questions that are sometimes asked by coroner’s inquests, these investigations focus on individual cases and do not enable us to address questions about the population as a whole. This study seeks to address that gap by compiling the first systematic database of flood and extreme weather casualties in the UK and using that unique dataset to consider the prospects for reducing the human cost of extreme weather in the UK in the future.

1.1 Introducing the themes

Disaster Risk Reduction focuses on mass fatalities in developing countries after high magnitude events, explained by theories of vulnerability. Natural hazards led to an average annual death toll of 69,827 people world-wide over the decade from 2006-2015, according to researchers from the Centre for Research on the Epidemiology of Disasters (CRED), who maintain the EM-DAT database of disaster losses for the World Health Organization (Guha-Sapir et al., 2016). Major disasters, like earthquakes, tsunamis, monsoon floods, and tropical storms are the biggest killers. These events leave multiple casualties in their wake, occasionally in their thousands, from drowning and trauma injuries. Many more die in the aftermath from secondary causes, including disease spreading as a result of disrupted water supplies and overcrowding in recovery areas. Overall, we
know that natural hazard impact discriminates, disproportionately affecting the poor and otherwise ‘vulnerable’. This is the case for both direct impact deaths, because poorer and more vulnerable communities may be living in areas of greater exposure and have fewer resources to prevent or avoid the immediate impacts of a hazard, as well as for secondary deaths, with the elderly and children at greater risk of disease. Thus, vulnerability theory informs disaster risk reduction practice for major hazards, targeting the poorest and the weakest; by protecting the vulnerable, the most deaths can be avoided.

The UK does not experience such extreme natural phenomena, which are confined to tropical and tectonically active regions. The UK’s greatest natural hazard risk comes from flooding; this is also true for most of Europe, where the European Environment Agency (EEA, 2017) estimates that “75% of natural disasters that have occurred in Europe since 1980 and around 64% of the damage costs” are attributable to hydrometeorological hazards. Surrounded by water, exposed to violent Atlantic weather systems, and representing a totally transformed natural landscape, the UK is at a high risk of a variety of flood impacts. One in every six properties in the UK is at risk from flooding; utilities are also vulnerable: 14% of power substations and 55% of water treatment and pumping stations are built on the flood plain (Thorne, 2014). Flooding in the UK comes from coastal, river, surface water or groundwater sources, and most events are in fact coincident floods, which makes them more complex to manage. The Environment Agency (Environment Agency, 2014) estimates that the average annual expected flood losses for England and Wales are £1.25 billion. However, few people are known to die in UK floods, and historically policy and investment has focused on protecting properties and assets.

Flood fatalities, however, are a real risk and a dramatic impact. Event mortality from fluvial flooding around the world is estimated at $4.9 \times 10^{-3}$ for pluvial floods and $3.6 \times 10^{-2}$ for flash floods (Jönkman and Vrijling, 2008). This is a high level of risk, significantly above the one death per one million population (i.e. $1.0 \times 10^{-6}$), which is a standard metric used to trigger risk reduction measures in many countries, including the UK (HSE, 1992) (HSE 1992). Global levels of flood mortality seem very high for the UK, but in the absence of any systematic analysis, it is difficult to say anything more definitive than that people do die in the UK from flooding, but how often and in what circumstances is unknown.
Fatalities in themselves are an interesting indicator of hazard impact. Their binary nature suggests that they may be easily countable and useful direct indicators of impact scale and severity. However, for lower impact hazards, like UK floods, fatalities and event magnitude may not have the same sort of linear relationship that can be observed in high impact disasters. Additionally, whilst vulnerability theory identifies the most likely casualties of major disasters, the people who die in UK floods may not be the same vulnerable populations. Just looking at the list of the five fatalities in the winter of 2013–14 shows that a generic vulnerability profile does not apply to these cases.

This thesis seeks to contribute to the body of knowledge about the most significant impacts of natural hazards—loss of human lives. Whilst recognising that there is a vast theoretical literature and practice on the risk to life from major hazards, like earthquakes and tropical cyclones, there is a lack of understanding of deaths in less extreme, but still significant, events. This is especially true for countries with developed hazard protection and response systems, and particularly true for flooding in the UK, where we do not even have a comprehensive list describing who died, where, and how.

1.2 The problem

Risk to life is the primary category of risk against which natural hazards managers seek to mitigate. According to the World Disaster Report (IFRC, 2014), over 60,000 people were killed by flooding (including waves and surges) worldwide between 2004 and 2013; in 2013 floods accounted for 44% of natural hazard fatalities. Death toll can be used as one of the measures for flood impact in the Global South, and past fatalities can become indicators of future risk (Smith, 2009).

The picture is quite different, however, in the UK. Whilst flooding has always been the most impactful natural hazard to threaten the isles, it is not, typically, a killer hazard. One in six UK households is at risk from flooding (Environment Agency, 2009), but historically lives claimed by floods are typically in the single digits for discrete events, with the exception of the devastating flood at Canvey Island in 1953 in which 58 people lost their lives (Di Mauro and de Bruijn, 2012).

To understand the flood risk to life in the UK we need to understand the nature of this risk, its magnitude and discriminations. The Emergency Disasters Database (Guha-Sapir et al., 2009) is
compiled and managed by the Center for Research on the Epidemiology of Disasters (CRED). The EM-DAT holds records on all types of natural and human disasters globally since 1900. A list of annual weather fatalities in the US is produced by the National Oceanic and Atmospheric Administration (NWS, 2017). At present, there is no recognised, verified or comprehensive list of flood fatalities in the UK. As a result, we know very little about the context or trend of flood fatalities in the UK. It is thus hard to know how best to save lives, or to evaluate success of avoiding fatalities, if we have no data to trace it.

For UK floods, we don’t really know who dies, where, how, and – crucially – why. However, the absence of data has not stopped the Environment Agency from trying to prioritise those identified as vulnerable in flood risk management (FRM) investment. The current flood incident management strategy is emphasising risk to life as an important priority, but we don’t actually know who is at risk or why, and even how great this risk is in reality.

1.3 The policy context

Flood risk management in the United Kingdom has historically used properties as the main impact indicator for policy and investment decisions. One in six properties in England is at risk from flooding; funding for flood protection increased by 75% between 1995 and 2000 (HMTreasury, 2005). Most of the investment is in protection infrastructure and maintenance. The majority of policies and publications from the Environment Agency for England and Wales focus on protecting properties and households exposed to flood hazards as a factor of their location. This has also been reflected in investment decisions and funding plans.

However, the new Flood Incident Management Plan is putting new emphasis on managing risks to life: protecting lives as well as livelihoods (Environment Agency, 2015). The explicit nature in which risks to life are addressed by this document is a notable shift from the historic emphasis on protecting property. An investment review in preparation of the FIM document presented evidence of risk to life from flooding (Wicks, 2013). This identifies a number of casualty case studies from known significant floods in the early 2000s, suggesting similarities in causes between them. However, it does not provide a systematic tally of deaths, and its scope for what is a flood death varies between events. The review recognises the lack of a comprehensive, searchable analysis of
UK flood death, which could help analyse the potential impact of FIM activities targeted at the likely casualties. As protecting lives becomes a policy priority, an explicit understanding of the nature of flood fatality risk is needed to fill this critical gap in knowledge.

The Environment Agency for England and Wales is informed by vulnerability theory in its flood risk management activities. It explicitly states a focus on helping those “least able to help themselves” (Defra and Environment Agency, 2011). In targeting properties for flood protection, the Environment Agency uses the measure of multiple indices of deprivation (Mclennan et al., 2011), which apply weightings to factors of deprivation across domains including income, employment, health, disability, education and training. Around a fifth of households on the flood risk register are classified as deprived and therefore more vulnerable (Environment Agency, 2009).

Scholarship into the concept of hazard vulnerability has evolved from positivist analyses of exposure to include underlying social, political, economic and cultural factors, which construct a vulnerable state (Blaikie et al., 1994). Vulnerability has come to be understood as a state when a combination of adverse factors like poverty, powerlessness, reduced mobility and marginality, renders individuals and their livelihoods susceptible to destructive hazard impacts (Adger, 2006).

These understandings of vulnerability have been operationalised effectively to address property risk and target support to vulnerable households. However, now that the Environment Agency appears to be directing efforts towards protecting lives, it is necessary to understand who is actually dying from flooding and other weather hazards. It would also help to know whether they are the same people as the vulnerable household occupants that the Environment Agency has focused on, borrowing form disaster risk reduction theory and applying it to the UK.

### 1.4 The research question

In 2013 King’s College London, alongside the universities of Reading, Newcastle, Bristol, Hull and others, secured a £2.7 million consortium grant from NERC to advance the understanding of causes and impacts of flooding from intense rainfall (FFIR). Project SINATRA (Susceptibility of catchments to INTense Rainfall and flooding) conducted research throughout the lifecycle of the FFIR hazard, from atmospheric drivers and forecasting, through catchment response and flood dynamics, to
modelling the impacts on lives, livelihoods and property caused by FFIR. This PhD research project is looking specifically at fatal outcomes of floods: who dies, where, how and why? If flood mitigation activities are to reduce the risk of death effectively, it is important to understand the types of individuals and communities that are most susceptible to these rare but extreme impacts.

To address the knowledge gap described above, this project compiled, for the first time, a comprehensive list of flood casualties, as well as deaths from other extreme weather events in the UK, for the 15 year period 2000 – 2014. Analysis of the gathered data will provide an opportunity to explore the following research questions:

- Who is dying from flooding and other weather hazards in the UK? What is the socio-demographic profile of a weather casualty?

- Are these the people we expect to be vulnerable? Do their social, economic, and physical characteristics predict them as vulnerable, according to the definitions and indices developed in disaster risk reduction theory?

- Can definitions of vulnerability be applied to risk of death from weather hazards in the UK?

1.5 Structure of this thesis

The thesis is structured in four parts. Chapters 1 and 2 present the background to the research question; Chapter 3 describes the methods used to build the new weather fatality database; results and discussion Chapters 3 through 8 present the findings from interrogation of the database; and Chapter 9 discusses the implications of the findings, making some policy-relevant conclusions.

Chapter 1 has outlined the need for addressing the issue of a lack of data on weather hazard fatality in the UK, as well as how little we know about the circumstances of these tragic incidents. It presented the context of flood protection policy in the UK, which is explicitly focused on preventing risk to life, but is not supported by detailed data on the circumstances of these risks.

Chapter 2 is a literature review of weather hazard impact scholarship, with a particular focus on literature addressing concepts of vulnerability. This exploratory exercise helped support the early
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hypothesis that flood casualties in the UK would not fall into the definition of vulnerable people at risk.

Chapter 3 presents a detailed methodological description of building up the weather fatalities database. It discusses the benefits and drawbacks of using newspaper reports as a source of data on death and places the study in the context of other fatality research methods. The first section describes the methodology applied to the gathering, filtering and analysis of data. This is a data-intensive study, which uses the LexisNexis® database of UK publications to select newspaper reports on flood casualties. Fatalities are rare enough and extreme enough to warrant a detailed and abundant interest from the media; these stories become a very rich source of information on the circumstances of the death. Systematically filtered and coded, the records become a comprehensive list of casualties.

The results of interrogating the database are discussed in five chapters, looking at the data from different angles. The results look for trends between fatalities and the nature of the weather hazard events which cause them. The analysis examines the fatality dataset in the context of other data sources, including meteorological time series, weather warnings, population and demography data. Each results chapter is prefaced with a short methodological note on how each section of the analysis was conducted. Weather fatalities in general, and flood fatalities in particular, are rare in the UK, compared to death by other causes. It should be noted that deaths from extreme heat or fuel poverty are out of scope for this study. However, there are clear and telling trends among the deaths recorded.

Chapter 4 presents overall hazard fatality totals and rates in the UK for the duration of the study period 2000 – 2014, recognising that the numbers are low and seemingly random. Chapter 5 seeks to explain the fatalities with a meteorological time series, investigating rainfall intensity and its temporal intersection with cases of flood fatality. Chapter 6 attempts to find trends in the geographical distribution of flood fatalities by mapping them and analysing the spread. Chapter 7 delves deeper into the circumstances of each fatality to understand if gender, age, activity or behaviour drives the risk to life posed by severe weather. The low number of deaths from extreme weather in the UK, and the victims’ lack of conformity to the “vulnerable” definition, which is evidenced by the findings, suggests that risk to life is largely avoided by hazard management
activities in the UK and that the magnitude of UK hazard events is not significant enough to cause major death tolls. In many ways the low number of fatalities are a testament to the success of risk mitigation and reduction policies. However, many of the residual fatal impacts could have also been avoided. To expand on this, the final analytical Chapter 8 explores flood and extreme weather warning systems in the UK in terms of their effectiveness in predicting events which caused fatalities.

Chapter 9 concludes this thesis with an in-depth discussion of the compounding variables which cause the low but significant number of flood and extreme weather fatalities in the UK. We unpack the definition of vulnerability in as far as it is applicable to these types of rare fatalities in countries with advanced disaster prevention and response systems. The final section draws conclusions about risk conceptualisation, warnings, and potential communication strategies, which may have policy implications.
Chapter 2 Understandings of Hazard Vulnerability

For the last several decades now, most natural hazard scholarship has recognised some form of source-pathway-receptor model of risk, in which “natural” disasters are in fact social constructs. In this constructivist framework, the human populations placed in the path of natural hazards are a necessary component of impact. Therefore, to understand the likelihood and magnitude of hazard impact it becomes necessary to focus on the receptor; the human population at risk. In this dimension, the concept of vulnerability becomes key in identifying which particular human receptors are most likely to come to harm in the event of a hazard. Vulnerability has been explored, defined, and redefined in many ways over the years. In effect, it has come to be an umbrella term and an all-engulfing concept which deals with physical and socio-economic ability to withstand and recover from hazard, voluntary and involuntary exposure through living in a hazardous location, and aspects of perception and decision-making which put lives at risk. Terry Cannon has concluded that “vulnerability has become so vague and abused that it is in danger of losing its analytical value” (Cannon, 2008b, pp. 351).

This chapter reviews research on natural hazard impacts, focusing in particular on mortality impacts, and discusses the different ways that the vulnerability of human populations to hazard impacts has been conceptualised in the literature.

2.1 Death in natural hazard scholarship

Weather related disasters, which represent 90% natural hazards occurring each year, caused the death of 606,000 people around the world between 1995 and 2015 (CRED, 2015). Overall, there is a downward trend in disaster deaths which can be observed globally over the last few decades, despite the growing global population. This can be skewed by rare and devastating megadisasters, like Cyclone Nargis which killed 128,000 people in Myanmar in 2008 (CRED, 2015), but the general trend is a reducing one. At the same time, the economic impact of disasters is growing rapidly. Whilst absolute economic losses are higher in developed countries in real terms (up to $150 billion is a single year), they represent a far greater proportion of GDP in middle and low income countries (0.1% of GDP for high, 1% for middle and 0.3% for low income countries). Overall, disasters are
becoming costlier over time, and affecting more people directly. However average annual mortality from weather related disasters has been falling globally since 2004 (Guha-Sapir et al., 2016). Policy efforts and understanding of natural hazard risks have made great steps in reducing loss of life, and in developed countries this reduction has been almost entirely successful.

To explore trends in death from flooding and extreme weather it is important to build a comprehensive picture of how the context of exposure and susceptibility to natural hazards is understood by scholars and regulators. The key concept important to this is that of vulnerability. There is a vast literature on vulnerability within the natural hazard field, and the term crops up in several other bodies of research.

This review of relevant literature is a non-exhaustive exploration of the meanings of vulnerability, its genealogy as a concept in natural hazard research, and its operationalisation by responsible agencies. The review attempts to map vulnerability in its relation to hazard impact definition and formulation.

The examination of fatality from natural hazard impact has always accounted for the vulnerability of affected populations. In the first instance hazards were seen as acts of God, which could not be predicted or prevented and only endured. With the development of modern science, natural hazards were transformed into risks, whose likelihood and potential impacts could be predicted in advance, allowing interventions to be taken in reduce their toll. There was an emphasis on the magnitude and frequency of the hazard, which led to emphasis on engineering-based prevention, such as dykes and dams to prevent flooding. The association was drawn between the biggest, most extreme events causing the greatest numbers of deaths, and this relationship was considered dominant and structural solutions were sought to reduce the impact of hazard by protecting people in situ with engineering solutions (Hewitt, 1983b). The conceptualisation of this relationship is still dominant today, specifically in policy and research, which focuses on the most destructive single impact events of greatest magnitude (Neumayer et al., 2014).

The recognition that behaviour and decision-making were an important driver of vulnerability first came from the joint work of Gilbert F White, arguably the father of natural hazard impact research, and his students Robert Kates and Ian Burton and their book *The Environment as Hazard*, in which their investigation of hazard event case studies culminated (Burton et al., 1978, 1993). Individual
decision-making is important in the degree of vulnerability experienced by people; many choose to live in hazardous and exposed areas for the associated benefits it brings. The authors consider how individuals and governments can “adjust” to mitigate levels of risk; much of G F White’s work covers non-structural flood plain management solutions for the reduction of impact through land use restrictions (White, 1961, 1971). The idea that behaviour matters and hazard induced choices are culturally bounded has been further explored in risk perception research in its relation to natural hazards and societal risks (Douglas and Wildavsky, 1983; Wildavsky and Dake, 1990; Burns and Slovic, 1993). Risky choices made by particular groups, which increase their relative vulnerability have been further identified in concepts such as the “white male effect”, which sees this segment of the population make the most positively biased risk behaviour decisions (Finucane et al., 2000; Kahan et al., 2013). However, this behavioural dimension, and its culturally bounded typology, has been largely overlooked in geography hazards studies.

With the dominant recognition of disasters as socially constructed and mediated by human and political processes, vulnerability concepts also evolved. Burton, Kates, and White were criticised for their individualist and voluntarist view of choice driven vulnerability, as well as for the presumption of a capacity to adjust. Vulnerability is a societally induced state, against which people had no recourse; power, poverty, justice, and political economy could not be ignored as the principle drivers of a vulnerable state, and people’s agency to “adjust” this is not a question of choice or capacity, but of marginalising political structures (Blaikie et al., 1994; Hewitt, 1983a; Wisner, 2001). This evolution in vulnerability theory brought to the forefront aspects such as age, gender, mobility, poverty, marginalisation as indicators of the vulnerable. Clearly evidenced by post disaster analyses of deaths in developing countries, the idea of discriminatory risk is a strong driver of policy and investment which seeks to protect the those most likely to come to harm as a result of their contextual and inherent vulnerability (IPCC, 2012; Guha-Sapir et al., 2016; Defra and Environment Agency, 2011).

The critique of behaviourally driven vulnerability is important in bringing out the underlying drivers of the most vulnerable population. However, completely overlooking behaviour leaves unexplained those hazard fatalities which cannot be immediately attributed to a vulnerable group. With protection
focused on vulnerable populations, questions arise about how often the “invulnerable” become victims of hazard, and what drives their situational vulnerability.

### 2.2 The origins and genealogy of the concept of vulnerability

The literature reveals that although the concept of vulnerability is a feature of many disciplines, including anthropology, psychology and engineering, it is only in geography and disaster research, where the subject is the human-environment interaction, that its meaning is contested (Adger, 2006)

(see Table 2.2-1).

#### Table 2.2-1 Terms used to describe vulnerability: A list gathered from the reviewed literature

<table>
<thead>
<tr>
<th>Term</th>
<th>Author</th>
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<tbody>
<tr>
<td>Susceptibility</td>
<td>Adger, (2006)</td>
</tr>
<tr>
<td>Powerlessness</td>
<td>Adger, (2006)</td>
</tr>
<tr>
<td>Marginality</td>
<td>Adger, (2006)</td>
</tr>
<tr>
<td>Degree of inability to cope</td>
<td>McCarthy et al, (2001)</td>
</tr>
<tr>
<td>Lack of entitlements</td>
<td></td>
</tr>
<tr>
<td>Deprivation</td>
<td>Walker and Burningham, (2011)</td>
</tr>
<tr>
<td>Elderly and infirm</td>
<td>Johnson et al, (2007)</td>
</tr>
</tbody>
</table>

Vulnerability theory in geography and disaster research has tended to shift towards one of two overarching bodies of literature: that of resilience of socio-ecological systems and that of livelihoods and poverty. The former tends to consider vulnerability as a parameter of natural hazard risk; the latter examines vulnerability arising from a lack of entitlements (Adger, 2006).

Most of the key literature agrees that adding vulnerability analysis to natural hazard risk assessment effectively produces a socio-economic and political prism through which to examine risk. Vulnerability arises out of socio-economic contexts of an individual or community exposed to hazard, and out of the political context of power relationships within and around these communities.

For a natural hazard scholar, this is an important lens for analysing the impacts of any extreme event by considering the contextual landscape struck by it. The spatial and cultural parameters of context vulnerability make these analyses richer, more specific and inherently geographical. It is
therefore unsurprising that the vulnerability concept has been such a prominent feature of disaster risk reduction research.

Burton, Kates, and White (Burton et al., 1978) consider the vulnerability characteristics of the interaction between forces creating hazard and opportunity. In this way, vulnerability is one of a number of several realities created by the event-exposure interaction. For these early commentators, vulnerability is a result where the flooding of a farmer’s field makes him vulnerable to economic loss. They saw hazard as an event interacting with institutional structures to create vulnerability. Therefore, increased economic activity, may increase rather than reduce vulnerability as it can have both mitigating and exposing outcomes. It is fascinating to trace the development of vulnerability as an outcome concept into a causal parameter in later works; a seemingly diametric shift in definition.

Figure 2.2-1 Visualising Burton et al. (1993): Vulnerability as a characteristic of circumstance.

Very soon in the development of hazard and risk research, the concept of vulnerability translates into one of power and entitlement analysis. Hewitt (2014, pp.141) describes the “human ecology of endangerment” in the context of calamity, where the poor and marginalised become most at risk due to their more exposed livelihoods. After this, the literature on vulnerability firmly settles into the paradigm of vulnerability equivalent to poverty and lack of entitlements. The overpowering observation that hazards and exposures affect different groups in society differently (Adger and
Brown, 2009) forms the backbone of vulnerability analysis, which becomes centred on investigating inherent social injustices and power relationships that create vulnerable communities. As vulnerability becomes synonymous with socio-political exposure, the concept seems to lose some of its dimensions, like the impacts causing vulnerability, or any changes in the status of exposure pre or post hazard. The use of the term becomes a political statement in itself: by identifying vulnerability the literatures name and label “the vulnerable”, designating them in need of special consideration for the purposes of mitigation. Conversely, the “invulnerable” would be the resilient populations, which tackle their own vulnerabilities through endogenous capacity-building measures. This dichotomy awards some agency to the exposed populations, empowered by actions towards resilience, and therefore reduced vulnerability.

The work of Blaikie, Cannon, Davis, and Wisner on the “pressure and release” model of hazard impact suggested the nature of hazards, together with the contextual vulnerabilities of societies, are both pressures that “crunch” the exposed unit to create the circumstances for disaster impact (Blaikie et al., 1994) (See Figure 2.3-1, page 28). Although Adger (2006) sees the Pressure and Release model as an integrating approach to physical hazard and entitlements theories of vulnerability, this integration is not explicit in the model’s early presentation. Like many researchers, Blaikie et al. (1994) focused on the contextual socio-economic vulnerability, and did not suggest that the inherent characteristics of hazards in themselves create vulnerabilities. The “crunch” model is taught as part of many disaster risk reduction modules, where Blakie et al. (1994) is typically a key text. As such, it has become phenomenally influential to at least one generation of natural hazard professionals. It is not surprising, therefore, that variations on the “crunch” model appear in policy documents and NGO reports, and the contextual view of inherent socio-political vulnerability permeates through the operational work of disaster risk reduction communities.

The paradigm of the vulnerable as the poor and marginalised has been explored in great detail (e.g. Cutter et al. 2003; Leichenko and O’Brien et al. 2008; Liverman, 1990; Watts and Bohle, 1993; Cutter et al., 2003; Turner et al., 2003). Many case study examples of this type of vulnerability have been described in the literature. Case studies have explored how poor groups in society are forced to live in areas exposed to hazard impact, although the opposite is often true when the affluent choose to live in exposed locations (Cannon, 2008b).
A key criticism of the vulnerability-poverty approach is that it largely ignores physical and biological systems pertaining to vulnerability (Adger, 2006) (see Figure 2.2-2). A number of attempts have been made to integrate the two approaches.

**Figure 2.2-2 Visualising Adger (2006):**
Vulnerability to natural hazard stress, vulnerability because of a lack of entitlements.

The integrated model from Susan Cutter goes further in identifying specific vulnerability contexts (1996; 2003) using the hazards-of-place model, wherein hazard potential (likelihood x mitigation) is subjected to a "geographic filter", which denotes the physical and social characteristics of a place that have inherent vulnerabilities (see Figure 2.2-3). This contextual place “filter” can increase or decrease the hazard potential depending on the nature and extent of these vulnerabilities. The work of Cutter and colleagues went a long way to “fleshing out” the understanding of vulnerability as more than a static characteristic of marginalised groups. In the 2000s more authors followed to balance out the term and give it multiple, but simultaneous, meanings.
It seems that O'Brien et al. (2007) finally reduced the debate to its component parts, which were to see vulnerability both as an outcome and as a contextual state. Whilst the two approaches come from fundamentally different discourses and in principle present vulnerability on different sides of a cause-effect model. The authors argue that the two paradigms are essentially complementary for climate change vulnerability analysis. They distil the two schools into “end-point” and “starting-point” vulnerability studies. For a climate change scenario, outcome vulnerability is the increased exposure of a unit to hazard created by the changing environment. Contextual vulnerability involves considering inherent socio-political factors creating vulnerability in the exposed unit before a hazardous stressor or change acts upon it. The scale of this inherent vulnerability then determines the scale of impact likely to be sustained. In turn, the impact of the hazard multiplies the state of vulnerability by a factor of both the ex-ante socio-economic state, and the ex post magnitude and intensity analysis. Therefore, reducing outcome vulnerability involves mitigation activity against the impact of a hazard event, whereas reducing contextual vulnerability demands changing the circumstances which the hazard will act within, so that individuals and communities become more resilient (see Figure 2.2-4).
O’Brien et al. (2007) suggest that the two approaches are complementary and can be applied simultaneously as part of risk reduction strategies. However, they find the integration of the two concepts problematic due to the different discourses from which they originate. Outcome vulnerability is rooted in the biophysical discourse and the scientific framing of climate change as an impact on human societies; contextual vulnerability comes from the critical discourse and the human securities framing of climate change, which recognises that different human societies are affected differently by the same impacts as a result of their socio-political contexts.

However, it appears that an integrated approach could be found in interpreting the two kinds of vulnerability as points on a hazard impact timescale. Here, contextual vulnerabilities create the conditions for impact, which in turn creates further outcome vulnerabilities that aggravate the initial contextual vulnerability conditions (see Figure 2.2-5). For example, if a farming community's livelihood is contextually vulnerable due to the small amount of land they own (as a consequence of the structure of the local political economy), the outcome vulnerability of a flood event exacerbates this by destroying the few crops available to them.

This integration of the physical and social applications of the vulnerability concept seems a much more effective way of analysing why the same event impacts communities differently, or why different communities suffer varying consequences form very similar events.

Figure 2.2-4: Visualising O’Brien et al. (2007):
Outcome and contextual vulnerability.
Although an integration of context and outcome is a clear way forward in the conceptualisation of vulnerability, the definitions in the literature remain temporally limited. Context vulnerability describes ex ante susceptibility to impact, outcome vulnerability analyses ex post changes to context vulnerability as a factor of hazard intensity and magnitude. What is missing from contemporary views on vulnerability is how it may change during the hazard event itself. Arguably, there is a behavioural parameter to vulnerability, wherein action choice exacerbates or mitigates both context and outcome vulnerability. That is to say, the farmer may choose to leave his limited, vulnerable land and evacuate his family as flood waters rise; this action choice increases the vulnerability of his crops (context), but protects the exposure of his family to drowning or waterborne disease (outcome).

In other words, vulnerability has been described in the literature as a state characterising two extremes of the hazard timeline. There is a gap in the literature, which could describe how actions during the event impact states and degrees of vulnerability.
The models in the literature have been driving towards a temporal integration of vulnerability concepts. By analysing separately context, then impact (which in turn becomes the context for the next event), the models have become a much better representation of hazardscapes than their early counterparts. But what about vulnerabilities created, and enacted, at the point of impact? i.e. the choices exposed people make, which enhance or mitigate exposure? The models lack a behavioural perspective, and therefore are difficult to apply to situations, where context and impact are more or less stable, but a single exposing choice to take a risk creates a moment of vulnerability. These types of events can be characterised as low intensity hazards, such as weather events, impacting highly developed and protected populations, like the UK. Disaster risk mitigation efforts equalise the contextual vulnerability by targeting protection to the susceptible, while the intensity of hazards is mild, compared to other regions of the globe. However, impacts still occur, lives are still lost. It is reasonable to assume that the missing piece of the conceptual model is the behavioural factor in the middle of the context-impact flow.
2.3 Vulnerability as poverty

Adger and Brown (2009) see vulnerability as the corollary of the capacity to respond to hazard, linking the concept closely to that of resilience. Neil Adger (2006) also notes that whilst resilience is often described in positive terms of capacity, ability and strength, vulnerability is a negative concept communicating a lack of the above, susceptibility and a weakness. Adaptation to environmental change requires resources, and hence it follows that those with the least resources have the lowest ability to adapt and are therefore the most vulnerable (McCarthy et al, 2001). The nature of the political economy of resource use is therefore inherently linked to degrees and concepts of vulnerability.

Much vulnerability research has sprouted from Amartya Sen's (1981) theory of entitlements (sources of welfare), where causes of famine are seen less as physical events such as droughts or floods, but resulting more from uneven patterns of access and entitlement in the context of war, disease, and socio-political structures. In a similar vein, vulnerability becomes the consequence of restricted access and the inability to command sufficient resource entitlements, which makes individuals less resilient to hazard impact. This is a key social science approach to vulnerability, and the vulnerable in this context become – almost exclusively - the poor and the marginalised.

Key contributors to this body of literature are authors like Piers Blaikie, Terry Cannon, Ian Davis and Ben Wisner (1994; 2009) who have progressed this line of research for the last twenty years and more. It should be noted that this approach focuses on disasters in the developing world, and may not transpose directly to flood risk vulnerabilities in the UK.

Within this research tradition, there is no such thing as a “natural disaster”, but rather the interaction of a natural hazard with existing social systems in a particular location. This explains why similar hazards affect different social groups differently. Blaikie et al. (1994) summarise this in the Pressure and Release (PAR) “crunch” model of disaster (see Figure 2.3-1).
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The PAR model sees the social construction of vulnerability (as exposure and lack of resilience), resulting from the framing of social structures and power systems (lack of entitlements, marginalisation) which are the outcomes of a wider political economy (contextual vulnerability). The PAR model brings together much of the preceding approaches to vulnerability in the social sciences by integrating the social construction approaches to the concept.

Terry Cannon (Cannon, 2008b) has provided an important perspective on this approach with the theory of “innocent disasters”. Whilst many disasters affect people who are “placed in the way” of hazard by exploitative social processes, as per the PAR model, at other times disaster affect people due to class-neutral factors of vulnerability, such as the choice to live in an exposed area due to desired ecosystem services. In a response to what he sees as the abuse of the term, Cannon calls for a more precise definition of “vulnerability” which may, or may not, be linked to poverty. Therefore, in disasters where the social construction of vulnerability relates to neither class, gender or other power relations, the disaster is considered “innocent” i.e. the people affected had become exposed through a socially constructed pattern of choices, not through marginalisation and inequality. From this conclusion of Cannon, we can make the theoretical leap to ideas of risk perception; where risk trade-offs, which are culturally determined, ought to be considered as part of vulnerability assessments.

Figure 2.3-1 "Crunch" Pressure and Release (PAR) model:
Adapted from Cannon, T. (2014)
Building on Cannon's exploration of culture, we can integrate the literatures on biases and heuristics, which are culturally loaded. Their inclusion brings us closer to a conceptual model of vulnerability which accounts for behaviour. It could be suggested, that behaviour at the point of impact creates vulnerability in the face of “innocent disasters”. Therefore, if we assess context vulnerability to be low (protected, affluent, informed), and outcome vulnerability risk to be low (insignificant flood, slow onset, low intensity), our “innocent disaster” can still have a lethal impact if it is met with vulnerability inducing risk-taking behaviour. The expanded definition can inform policy as it enables us to identify where on the event time scale to target our mitigating interventions. Does it matter if a house is uninsured when the behavioural risk is greater than the risk of exposure? Will targeted warnings protect better than raised foundations? How do we choose the instrument and the point of its application? A conceptual model of vulnerability, which accounts for choices made during the hazard event can help target warnings and information, as well as emergency responders.

2.4 The influence of scholarship on policy

Several important authors have investigated the concept of vulnerability to flood impacts in the context of UK flood risk management. Some of the seminal studies relate to dated flood risk management contexts, but still demonstrate the link between vulnerability theory and flood policy action. This section critically reviews some of the key research in this area, before considering vulnerability in more recent policy and practice.

Brown and Damery (2002) identified vulnerability to flooding as a factor of exposure, which is amplified by population growth pressures and building strategies. However, the authors note that relying on such definitions can bring about an “undersocialised” understanding of vulnerability, assuming a heterogeneous exposed community with equal abilities of resilience and adaptation. However, an “oversocialised” understanding of vulnerability is equally unhelpful in the context of flood risk, as the human elements cannot be prioritised over the physical nature and dynamics of flood impacts. What Brown and Damery notice, is that flood management at the turn of the century had been focused on deterministic definitions of vulnerability, alongside rigidly quantitative indices of exposure, severity and social characteristics. They call for an integration of other contextualised
elements, such as perception, local coping strategies and support networks. Although the authors do not go as far as identifying behaviour towards vulnerability as a missing piece, their insistence that perceptions have a role to play in forming vulnerabilities shows that the literature becomes more integrated and more detailed as scales of enquiry zoom in on developed countries, like the UK.

Johnson et al. (2007) consider the “fairness” of flood management policy in England, both in terms of government investment and event management practices including insurance, warning, emergency response, etc. “Fairness” is considered in terms of vulnerability and equality parameters. The authors identify different principles of “fairness” in flood management: (1) equality - equal opportunity for flood protection for all, (2) maximum rule - targeting resources to the most vulnerable, and (3) maximising utility - assisting those who can benefit most from the support. The authors conclude that England’s Flood Risk Management (FRM) policy is a pluralist approach, incorporating all of the above elements through large-scale expenditure on flood defence (1), targeted assistance to vulnerable members of society (2), and risk-based prioritisation of intervention (3). Johnson et al. identify many policy documents used by the Environment Agency and Defra (e.g. PPS25), which specify vulnerability-targeted FRM, within which highly vulnerable population dwellings are identified as “elderly or other people with impaired mobility, residential institutions such as care homes, children’s homes, and gypsy and travellers sites” (Johnson et al, 2007, p.286). The response of the emergency services is also reported as focused on the most vulnerable i.e. elderly and infirm.

Conversely to the integration efforts of Cannon (2008) and Brown and Damery (2002), the review by Johnson et al. (2007) demonstrates that England’s policy in the early 2000s was firmly fixed in the contextual vulnerability paradigm. When policies specify the immobile, the marginalised and the weak, the clarity of the agenda is evident. Although risk assessment may take into account the magnitude of the hazard and the potential impacts, vulnerability analysis is firmly fixed in the pre-event circumstances. Behaviour and perception remain unaccounted for.

This analysis resonates with the stated Environment Agency focus on helping those “least able to help themselves” (Environment Agency, 2001). In targeting properties for flood protection, the Environment Agency has historically used the measure of multiple indices of deprivation (DCLG,
which apply weightings to factors of deprivation across domains including income, employment, health, disability, education and training. Around a fifth of households on the flood risk register are classified as deprived and therefore more vulnerable (Environment Agency, 2009).

Walker and Burningham (2011a) go further to consider the environmental injustices of flood risk management. They make the case that flooding is a distinct environmental risk due to the interplay of natural and technological aspects of hazard. The environmental justice framing of flooding is closely linked to the analysis of underlying patterns of environmental inequality, and therefore suggest and entitlements approach to vulnerability definitions. The patterns of uneven exposure to flood risk, which are often a socio-economic outcome, in effect create physical vulnerabilities of exposure. The paper provides examples of exposure analyses where a positive correlation trend can be observed between degrees of deprivation and exposure to sea flooding (via flood risk zone residence). However, a similar analysis suggests that river flood risk is equally distributed across socio-economic groups. This provides clear evidence that only certain types of flooding interact with contextual vulnerability of exposure linked to economic inequalities.

The limitation of the analysis is that it is mostly relevant to property impact, as that is how policy has historically defined exposure. This discriminates positively along income indices, identifying poorer and uninsured households as most exposed. Where the dwellers of those and other households are at the time of impact is not a dimension which fits into the model. Therefore, both behaviour and event magnitude are excluded from the analysis.

Looking at other examples of contextual inequalities, Walker and Burningham (2011a) provide evidence that more deprived demographic groups are more likely to inhabit types of dwellings which are least resilient to flood impacts (e.g. caravans and mobile homes). Similarly, we can infer that deprived households are less likely to have contents insurance, making them less resilient to the consequences of flood impacts. Other studies have proved that the lack of a disposable income “buffer” makes poorer communities less able to recover after the event: Walker and Burningham (2011) demonstrate that patterns of economic injustice are the enablers of many aspects of contextual vulnerability, effectively translating the concept of vulnerability as a lack of entitlements, into the context of UK flood impact vulnerabilities. The authors further demonstrate the contribution
of age, gender and cultural factors to contextual vulnerabilities, echoing the vulnerability as poverty literature.

2.4.1 Vulnerability is UK flood policy: evidence of absence?

Flood risk management in the UK is a devolved area of policy, but the structure of responsibility is similar across the administrations to that of England, which is split broadly into three levels (summarised from Porter and Demeritt, 2012; Pitt, 2008; Smith et al., 2017; Environment Agency, 2009):

- European and National policy
  - EU Floods Directive 2007, sets out the requirement for flood risk management planning
  - Department for Environment, Food and Rural affairs formulates policies in accordance with:
    - Strategy: Making Space for Water 2005
    - Legislation: Flood and Water Management Act 2010
- National strategy and planning
  - Environment Agency defines and implements some of the long-term flood mitigation strategies through its local partnerships
    - Flood Risk Management Plans (2015-2021) work on a six year cycle and are defined for 11 river basins in England and Wales. They define the risks and responsibilities of authorities including the Environment Agency, Highways England, lead local flood authorities, and other local actors.
    - Catchment Flood Management Plans are more detailed local catchment plans (77 for each river catchment in England and Wales) produced by the Environment Agency.
    - Shoreline Management Plans
- Local level operational flood management
  - Lead Local Flood Authorities, usually the county or unitary authorities, working together with drainage boards and water companies.

Historically, the UK had taken the flood defence policy route, with hard engineering solutions prevailing in low lying coastal and agricultural areas; dredging, pumping, and constructing embankments kept may areas protected. Some of this can be traced back to the response to the North Sea floods of 1953, which caused 307 deaths and over 30,000 people were evacuated, with the majority of East Coast flood defences destroyed (Di Mauro and De Bruijn, 2012). However, a constant driver was the risk to farm profitability and the requirement to protect agricultural productivity, as well as urban assets (Johnson and Priest, 2008). An engineering focused response, featuring multiple coastal flood defence projects, land drainage and the eventual construction of the Thames Barrier was the main policy driver of the following decades. A feature of contemporary flood policy was its growing centralisation, with a East Coast wide flood warning system and a national river gauging programme, the adoption of national standards for flood defence, and
eventually the centralised responsibility for flood risk management first by the National Rivers Authority, and finally by the Environment Agency in 1996 (Penning-Roswell and Johnson, 2015).

Up until the 2000s, a clear mandate from the government to protect property and keep water out can be traced in flood policy activity (Johnson and Priest, 2008), with the vulnerability centred on urban assets rather than farmland drainage. Partly in response to the major floods of 1998 and 2000, and in a context of growing recognition of environmental impacts, post-2000 flood risk management became less focused on ‘hard’ solutions, shifting in favour of flood warning and awareness raising, growing insurance safety nets, and developing recognition of local knowledge as key to flood risk management activities. The clearest policy shift was observed with the Making Space for Water national flood strategy (2005), which acknowledged the impractical reality of holistic flood defence and signalled a move towards flood risk management, and softer solutions, more in tune with nature (Smith et al., 2017).

An important feature of post 2005 flood management policy is its decentralised and multi-actor nature, which has been argued to lead to greater transparency and inclusivity of community needs in flood protection decisions (Johnson and Priest, 2008), and at the same time to a lack of coordination and clarity about responsibility during event onset (Smith et al., 2017). In this context, even if a vulnerability paradigm informs the high level national policy for flooding, the degree to which it permeates to the operational level will vary regionally, locally, and by event.

UK flood policy has been characterised by relatively dramatic shifts following major flood impacts and subsequent public and political scrutiny (Smith et al., 2017). Public, political, and media discourse in the immediate and short-term aftermath of an event creates a ‘window of opportunity’ for significantly advancing, if not dramatically changing flood management policy via sudden tangible shifts where floods act as “catalysts for change”, as described by Johnson, Penning-Roswell, and Tunstall (2005).

Often characterised as reactive, flood policy shifts in England have been documented after major events. The floods of 2000 were widespread and characterised by significant impacts in multiple locations, but fragmented in a way which implied national level ‘hard’ engineering approaches would have been ineffective (Bubeck et al., 2017). The floods of 2007, more regionally concentrated with significant community level impacts in Gloucestershire, prompted a national level review (Pitt,
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2008), which recommended a risk management approach to flood policy, with warnings, insurance and community resilience as top considerations. The 2010 Flood and Water Management Act and subsequent FRM activities embraced the message of resilience; one of the key responses from the Environment Agency was building awareness amongst communities, focusing on those described as “vulnerable”, namely the elderly, parents with young children, and low income families (Defra, 2012).

The most striking example of a responsive policy shift, however, was the return of dredging as a focal response to the Somerset floods of 2013/14, promoted by political and media discourse, with less review of local needs and vulnerabilities (Smith et al., 2017). It could be argued, that the rapid advancement of policies ex-post, with a preference of hard engineering solutions in favour of holistic and integrated catchment management, ignores the vulnerabilities of communities at risk which can find it difficult to secure funding, driving social inequalities further and exacerbating in situ vulnerability.

2.4.2 Vulnerability in action: operationalising the term

The various strands of vulnerability theory are transposed into action by the Environment Agency's flood risk management (FRM) activities, emergency management responses, flood insurance, and planning policy.

Emergency management activities in the UK, which are enacted in response to major flood events, are defined by the Civil Contingencies Act (2004). The framework for emergency management is integrated both temporally (before, during and after an event) and sectorally (bringing together multiple actors for coordinated response under category-1 and category-2 responder levels). At the same time that FRM became partially devolved and decentralised, emergency management also evolved to feature community resilience programmes and Local Resilience Forums, which represented participatory local emergency management, where emergency communication and response was defined at local level (Begg et al., 2015). It is likely, that under a devolved and decentralised framework, vulnerability takes on multiple definitions at the operational level and with diffused government responsibility to protect everyone, some vulnerable individuals may be at greater risk. The localism drive for emergency management under the Coalition government, which enabled parish councils local community networks to establish their own emergency response
plans, may have had an exacerbating impact on exposure of vulnerable individuals. On the other hand, by emphasising individual awareness and responsibility, it may have had an enabling effect on other vulnerable groups.

Additionally, vulnerability approaches are operationalised through approaches to flood insurance. In the UK private flood insurance for at risk properties is ubiquitous, but unsustainable costs and premiums were identified in review of major events in 2007, 2012 and 2013/14. Since 2016, Flood Re has enables a cap on high flood risk household policy premiums, with the remainder of uncovered loss covered from an industry wide pool drawn form a common levy and all domestic flood policy premiums. The result is a policy which benefits, and effectively subsidises household in the highest flood risk prone areas, whilst charging everybody (Penning-Rowsell et al., 2016). This represents an exposure-based approach to vulnerability, identifying the geographical spread of risk and focusing on properties without the contextual vulnerability of their inhabitants, and their relative availability to pay for insurance. The Flood Re approach to vulnerability, and its implied inequality, is at odds with other examples of operational approaches to vulnerability, which are very context centred, classical interpretations of vulnerability as lack of capacity to withstand impact.

One of the key areas of vulnerability analysis within this framework can be identified in the flood risk assessment requirement of the planning application process (Environment Agency, 2014). The requirement for a flood risk assessment is proportionate to the level of exposure and vulnerability assumed for each application: i.e. FRA guidance is dependent on exposure parameters (location by flood zone, type of project by size: <250m², < 1ha, > 1ha) and degree of contextual vulnerability of the project (specifically for projects in Flood zone 2 at <1ha). Under the specified degree of vulnerability, the developer must report various degrees of information, with greater levels of scrutiny applied to projects classified as “more vulnerable”. The Local Planning Authority can refer to guidance thresholds of acceptable flood risk, as stipulated by the Environment Agency guidance. The operationalisation of the vulnerability concept in this sense is risk-based, with greater levels of exposure and project size influencing the category of vulnerability under which each project must report their flood risk assessment.

The delineation of vulnerability categories in this process comes from the National Planning Policy Framework Technical Guidance document (DCLG, 2012). The NPPF was developed in 2012 to
amalgamate a broad set of planning guidelines, including those under PPS10 and PPS25, into a single national policy which would be concise and easy to apply. As often happened with overarching policy almanacs, the resulting document omitted a great level of detail necessary to fully understand the reasoning behind it. The technical guidance includes a table of “flood risk vulnerability classification” (DCLG, 2012, p.6) which is intended to be a comprehensive classification of vulnerable infrastructure, specifying which types of infrastructure require a flood risk assessment and a warning and evacuation plan. (It should be noted, that as this is a document to aid the development of static assets, the vulnerability analysis does focus on infrastructure rather than people.) The document divides infrastructure into the following categories of vulnerability:

- Essential infrastructure (including transport and power generation);
- Highly vulnerable (including emergency services and hazardous stores, but also caravans and basement dwellings);
- More vulnerable (including hospitals and health services, education and halls of residence, care homes, but also some places of leisure – drinking, hotels and nightclubs, as well as hazardous waste management facilities and landfills);
- Less vulnerable (including commercial and office spaces, other places of leisure, restaurants and cafes, industrial uses which do not include hazardous content); and,
- Water-compatible development (including flood control, river and marine installations, water-based recreation and amenity open space).

It is interesting to observe the NPPF’s use of the vulnerability concept within this classification. On the one hand, there is a great deal of emphasis placed on the inherent, or contextual, vulnerability of the installations, based on the people and activities it contains. In the highly vulnerable category this includes those space users who are vulnerable due to lack of capacity to act (care homes, education establishments, health services – elderly, children, sick). This feature resonates with the vulnerability as a lack of adaptive capacity literature, where the vulnerable are those who are less resilient to change. It is loosely connected with the vulnerability as a lack of entitlements literature, as the reduced resilience also suggest the reduced command of resources and access to entitlements, although the support network contexts in which these “residents” are found should improve this “deficiency”.

However, the inclusion of specific types of leisure premises (drinking establishments, nightclubs and hotels) indicates a different outlook on the vulnerability of residents. There is an assumption on behalf of the NPPF document that these activities are associated not only with an increased number
of people concentrated in one exposed facility, but also with a reduced ability to respond to hazard – a temporary loss of adaptive capacity amongst an otherwise resilient population. This loss of capacity seems to be associated with inebriation (drinking establishments), distraction (nightclubs) and possibly a transfer of trust (hotels) where one’s safety and alertness is transferred to the host, potentially because of a lack of familiarity with the location. The basis for this approach has not been identified so far in the reviewed literature, and could be of particular interest to the wider study on flood fatalities.

On the other hand, the NPPF classification is also significantly concerned with impact, or outcome, vulnerability. We see the proportionate inclusion of facilities which are either inherently hazardous themselves, or critical to resilience and recovery. The failure of power generating infrastructure, emergency services or major road networks as a result of hazard impact creates vulnerability in the “downstream” populations, whose main resilience resources are dependent on the stability of these systems. Similarly, the graded inclusion of hazardous content infrastructure reflects the outcome vulnerability created by the potential breach of these facilities as a result of hazard impact.

It therefore seems that the NPPF is in fact demonstrating an integrated model of vulnerability above and beyond the theoretical approaches reviewed above. However, the classification list is not exhaustive, and the reasoning behind its structure is not entirely clear. This policy tool requires further analysis to understand how it has been put together and whether it is a useful operational understanding of vulnerability.

The NPPF classification is in part based on an earlier Defra research documents analysing Flood Risks to People (Defra, 2006). The Risks to People Project was developed in the context of a source-pathway-receptor model of risk, which has been widely applied by Defra across a range of hazards. As Figure 2.4-1 denotes, the model also includes elements of integration of various concepts of vulnerability.
Looking closer at the concepts of “area vulnerability” and “people vulnerability” within the document, we find the former is a very literal transposition of the concept of physical exposure, both geographically (flood zone) and architecturally (low rise versus high rise); the latter denotes people’s “ability to respond to ensure their own safety” (Defra, 2006, p.4), placing it firmly within the vulnerability as adaptive capacity paradigm. The concepts are used in tandem to develop flood vulnerability maps, which superimpose both kinds of vulnerability to identify the most vulnerable areas. Crucially, the assessment of people vulnerability relies on two specific variables: the percentage of elderly and percentage of long-term illness within the population. The document goes on to specify vulnerable populations in one of its key guidance statements: “Vulnerable people (the old, disabled and sick) are less able to cope with floods than others and are therefore at greater risk… People Vulnerability depends on the age and physical condition of the people exposed to a flood” (Defra 2006, p.14). This relates directly to the contextual vulnerability concept, relying on qualities and abilities of people to communicate their vulnerability.

From these current policies we see that contextual vulnerability, and a focus on “vulnerable” populations least able to react and adapt, are deeply rooted within the regulatory frameworks, which govern in planning and flood management in the UK. The contextual vulnerability paradigm informs regulatory activities to a significant degree, with most targeting of effort and resources easily traced back to a simplified Burton et al. (1978) model. Outcome vulnerability is less prevalent within flood vulnerability.
regulation, perhaps due to the fact that recovery is heavily influenced by the insurance sector and response is delegated to local authorities.

There is a focus on drivers and people on the road in the policies and methods connected to warning systems (Environment Agency, 2015) In this way, the Environment Agency identifies a moment of vulnerability not reported in the theoretical models. The basic understanding that exposed individuals are not always located within exposed assets is an operational truth poorly conceptualised in the literature. In this way the operational understanding of, if not vulnerability, then temporary exposure, is more advanced than the theory which informs it.

2.5 Conclusion: How the literature informs this study

Vulnerability sometimes fits rather clumsily into the conceptual formula of risk. The literature does not agree on the relationship between vulnerability and exposure, vulnerability and resilience, and whether these are separate or derived elements of the risk equation. However, all of the literature agrees that the same hazard event has different impacts on different groups of society. And conversely, we can infer that similar social groups are impacted upon differently by hazards of different magnitudes. However, there is a lacking explanation of why homogenous exposed groups respond differently to hazards of a similar magnitude: it is here that a behaviour, choice and trade-off literature has its place in explaining vulnerability.

Within natural hazards, vulnerability has often been a somewhat single-track notion, identifying elements of resilience which are lacking in certain communities, which reduce their ability to withstand and recover from hazard impacts. Within this logical framework, the concept of vulnerability has most often described the poor, old and/or immobile. Building on the scientific literature concept of the vulnerable, many regulatory and active bodies have also come to define the vulnerable as the incapable or incapacitated.

However, looking at evidence of the few flood fatalities in the UK from recent years, it appears that many casualties have been far from impoverished or disabled, but rather professional, active, and mobile. Compared to tropical regions, the UK experiences relatively low impact floods, surges and windstorms, yet still there are some casualties. Therefore, it is crucial to understand how we define
vulnerability, for whom and under what circumstances, to make sure activities such as risk communication and warning reach those most likely to put themselves at risk, alongside those most likely to receive rescue.

Ultimately, risk of death from flooding remains an issue, even though fatality numbers are falling. Although significant efforts have been successful in reducing loss of life from flooding, certain vulnerabilities remain. The UK’s National Risk Register considers coastal and inland flooding as risks of significant national magnitude, with the potential impact severity on the same scale as pandemics, industrial accidents, and major attacks (Cabinet Office, 2008). However, there is a clear lack of data on actual historic mortality impact of flooding in the UK, and consequently a gap in the understanding of the drivers of vulnerability to this hazard impact. This PhD thesis project developed a robust methodology for gathering and analysing this data, in order to test the relevance of classic definitions of vulnerability to flood hazards in the UK.
Chapter 3 Methodology: Gathering Fatality Data

The project set out to create a database which did not previously exist. Fatalities from UK flooding have not been systematically recorded as an exclusive dataset by any institution or body involved in flood risk management. Many policy initiatives consider death from hazards as a risk and an issue, but in the UK there is no comprehensive evidence base for this. Gathering fatality data can help to illustrate the claim and investigate whether it is, in fact, a big problem for those reasons which we have come to assume.

In considering fatal disaster risk, there is a tendency to focus on sudden onset and high magnitude events and to miss out smaller or chronic onset hazards, which are more difficult to track and report. When counting weather casualties, it is important to define them as such by proving that the death resulted as a direct and immediate result the hazard. There are large numbers of weather-related deaths which may have occurred after the event, as a result of post-traumatic mental and physical health impacts, as well as changes in circumstance, such as loss of a home. These are notoriously difficult to estimate and capture in disaster accounting, and so most studies focus on direct death impacts at the point of hazard. This consideration is especially important for the analysis of extreme temperature events such as heat waves or extreme winter cold, which affect many people, but are exacerbated by pre-existing health conditions and frailty associated with age. Although these deaths must be accounted for in any ex post hazard analysis, they do not exclusively represent hazard impact and make it difficult to compare impact intensities like for like. Partly for this reason of effect magnitude, and partly for the complexity of definition, extreme temperature deaths have been excluded from this study.

3.1 Existing evidence

The majority of research into flood death falls into two basic types. Most significant flood events are followed by a number of "post-mortem" analyses of cause and impact. Key studies which informed the methodology of this project included the analysis of the 2002 floods in Gard, Southern France by Ruin et al. (2008), Kellar and Schmidlin's (2012) investigation of flood deaths in the United States between 1995 and 2005, the detailed account of the 1953 flood on Canvey Island (Wicks, 2013),
comparisons of the events which devastated the French Atlantic coast during storm Xynthia in 2010 and floods in the Var region in the same year (Vinet et al., 2012), ex-post surveys of people affected by the 1997 Red River flood in Manitoba (Buckland and Rahman, 1999), and an important piece which compiles a range of US flood case studies into a single analysis of the causes of fatality (Terti et al. 2016).

One of the drawbacks of this event-based case study approach is that there is an inevitable bias to look at larger events. Consequently, deaths from less significant floods may be overlooked. This case study bias, and the reactive nature of these analyses makes them illustrative to the discussion of fatality causes, but far from comprehensively telling of impacts on a larger temporal scale.

On the other hand, there are a number of large open access international databases, which document the occurrence of hazard events, their magnitude and impacts (Tschoegl, 2006), sometimes including fatalities:

- The Emergency Disasters Database (EM-DAT) catalogues large scale impact disasters since 1900 globally;
- ReliefWeb, run by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) provides live information of hazards events as they unfold;
- The International Flood Network (IFNET) cataloguing large (>50 deaths) floods since 2005;
- The Dartmouth Flood Observatory (DFO) Global Archive of Large Flood Events, documenting floods since 1985; and,
- The Global Flood Inventory (GFI) (Adhikari et al., 2010) of events from 1998 to 2008, compiled from an integration of the above databases.

Most of these databases rely on official government information, cross-referencing and additional sources, including the media. The DFO database relies heavily on newspaper reports as a primary source, whereas the GFI uses them for verification purposes. However, no databases that use newspaper and media reports as the main source of primary data were identified.

Additionally, the US NOAA maintains a record of annual weather hazard related deaths in the USA, which include flooding amongst other hazards (NWS, 2017).

However, in the case of all these databases, there is a clear tendency to overlook small, local flood events, and incidents which caused few deaths. As such, the UK does not even feature in several of the databases as there have not been any large multi-fatality events in several decades. Even
EM-DAT, which is overall probably the most detailed source of flood mortality data, overlooks a number of smaller but fatality inducing flood events. Additionally, the wealth of qualitative data about the circumstances of fatality is never reported by the large databases, providing little insight into the contextual causes of vulnerability.

Informed by the existing evidence, this PhD project developed a methodology which could bring together the strengths of both fatality reporting approaches. By looking at all deaths during a particular study period (2000 – 2014), it generated a high level account of deaths from a number of events, and could look for trends over time. By extracting multiple types of information on each death, the developed database delivered a similar level of contextual and qualitative analysis found in the case-study approach.

3.2 Why news reports are a good source of fatality data

This study has used newspaper records to compile a list of fatalities from flooding, storm, wind, and snow events in the UK since 2000. Direct death from weather hazards is the most significant impact, against which first responders aim to protect.

Printed, televised, digital, and social media is the primary source of hazard impact information for the general public. These reports can provide rich and immediate data on the scale, intensity and impact of the hazard.

Using newspaper articles as a proxy for hazard impact reports is a well-established practice in natural hazard research. Newspaper reports are a richer source than official records for information on the spatio-temporal expanse of the impact, the varying levels of response in different locations, and how the event was perceived (Williams, 1981). Information and impressions can be harvested both from the general trends in reporting and from closer analysis of individual articles (Escobar and Demeritt, 2012).

There is a strong record of using non-scientific accounts to reconstruct natural hazard events and of the use of newspapers as historical data in particular (Trimble, 2008). The digitalisation and indexing of multiple newspaper archives has made this method more accessible and efficient for building, expanding and verifying large inventory and impact datasets. A recent study of UK
landslide occurrence, for example, used newspaper coverage to identify 111 events to complement the National Landslide Database, and enhanced the breadth and detail of information for existing entries in the Database (Taylor et al. 2015).

Newspaper records have been successfully employed to build a picture and a comprehensive impact analysis of specific historic flood events. Tarhule used newspapers to explore the nature of flood events in Niger's Sahel (Tarhule, 2005); Hall traced a turning point in the expectations about state responsibilities for natural disasters in the UK (Hall, 2011) and Escobar & Demeritt used newspapers to document shifts in the public perception of flood risk in Britain (Escobar & Demeritt, 2014). The events of two major floods in Red River Valley, Manitoba were reconstructed exclusively from news articles (Rashid, 2011); this provided a detailed account of the floods, but also their perception and framing. Data on victims from the summer 2002 floods in the south of France was extracted from media sources and data from municipal and emergency services (Ruin et al., 2008). The authors of this study note that inconsistency in the classification of casualties in official statistics made it very difficult to identify deaths caused directly by the flood. In this case, using descriptions from news reports is more reliable.

Finally, newspaper records are an excellent source of data for building time series of flood events in particular catchments and basins. This approach greatly extends the timescale considered (Sutcliffe, 1987), as historical archives go back further than official hazard impact statistics. This can improve the ability to identify trends and develop frequency and risk estimates (Werritty et al., 2006).

The use of newspaper records for this study is justified by their abundance, historical scope, reporting detail, specifically on the details and characteristics of flood victims, and the limitations of alternative sources, the lack of data on individual victims in official databases, and the misclassifications prevalent in death statistics.

3.2.1 Using the LexisNexis® database

The digitisation of printed media has been gaining pace over the last decade, especially with the contributions of major global enterprises, like Google and Amazon. The major digital repositories for UK print media are the British Newspaper Archive (British Library, 2015), which host publications from 1800 to about 1950, and the LexisNexis® database. Originally designed as a resource for
legal research, the US based LexisNexis® digital archives have become a primary subscription resource for many academic research projects using reporting media as a data proxy (Deacon, 2007). The database hosts digital searchable versions of individual articles published in 568 UK newspapers since the 1980s (Taylor et al., 2014), and 36,000 news sources worldwide. Coverage becomes more comprehensive in more recent years; most publications are included from around 1998 (Deacon, 2007). However, articles may take up to several months to be uploaded, so very recent coverage is less complete.

3.3 The process step-by-step

The method applied to extracting the fatality data from LexisNexis® followed the following broad steps:

1. Conducting exploratory searches and trials of the LexisNexis® database
2. Constructing the Boolean search protocol
3. Searching the database systematically on a month-by-month basis
4. Downloading an initial corpus of articles meeting the search criteria
5. Transferring into a spreadsheet format and skimming for relevance
6. Extracting and coding relevant information from the remaining articles
7. Finalising the list of casualties and their contexts

3.3.1 Exploratory searches of the database

The study has considered deaths occurring as a result of extreme weather hazards typical to the UK, including floods, storms, strong winds, and snow storms. With scarce statistics available on these types of casualties, this dataset was chosen to fill a knowledge gap. With first responders and the Environment Agency the likely beneficiaries of such data, only such hazards as would be in scope of their response were considered.

The LexisNexis® database has a useful interface for entering search parameters and filtering results. Certain secondary minor sources of news, like newswires or website news can be excluded, but were retained for this analysis to ensure a comprehensive dataset. Duplicate articles (for
example form the morning and evening edition of a paper) were grouped automatically using the system’s similarity protocol.

![Figure 3.3-1 Example of LexisNexis® search window with a pilot search](image)

**Figure 3.3-1 Example of LexisNexis® search window with a pilot search**
The system allows for the use of complex Boolean operators, in combination, custom dates and publication sources, as well as the grouping of duplicates using an automatic similarity analysis.

Several exploratory searches were carried out to generate sample sets of articles about flood impacts, and develop a range of search and exclusion criteria for the Boolean search protocol. The exploratory searches used known flood events or well documented periods of time to test the additionality of the LexisNexis® database.

### 3.3.1.1 Choosing sources

The exploratory searches trialled different combinations of sources available in the database. Nexis' Multiple-source files include options such as UK Broadsheets, UK Nationals, UK Regionals and UK Publications, which is the most comprehensive one. It also includes an option to search in UK Newspaper stories but in this case only selected online coverage is included. A trial search was performed on the regional newspaper database, which returned results from relevant regional publications but also included national publications, such as The Times, The Independent and The Telegraph. The data reported in the national publications was found to complement and consolidate the regional data rather than repeat it. Thus the sources were set as UK Publications to ensure both regional and national sources were fully captured.
3.3.1.2 Grouping duplicates

Nexis groups duplicates using either High or Moderate Similarity criteria. The system chooses a lead document within a group of duplicates and then excludes the rest. The aim of using this option was to filter out duplicating articles e.g. from morning and evening editions of the publication, or duplicated within the online version that increased the volume of articles for analysis without contributing to the quality of the data. During trials, using the High Similarity option was not found helpful and even the Moderate Similarity option results still contained a number of duplicates, which had to be filtered out manually, so the decision was to apply the Moderate Similarity option to reduce duplicates as much as possible.

3.3.2 Developing the search protocol

Boolean search terms allow for more sophisticated textual data mining methods than simple word searches. For the purposes of this study, the search terms needed to be consistent for the timescale under consideration, applied consistently to each month’s corpus of articles. They also needed to capture all possible fatalities resulting from weather events, so that each could be individually assessed as within or out of scope. They also needed to generate a reasonable degree of relevancy in the returned records, minimising false positives such as “floods of tears” or “messages flooding in”. Having run a number of test searches, it was seen that flood fatality reports are often included in articles about other weather hazards, such as storms which cause flooding. Based on this observation, the study was expanded to include deaths from other weather hazards, specifically storms, gales, and blizzards.

3.3.2.1 Constructing Boolean search parameters

Nexis allows for the search to be carried out in the headline, headline or lead as well as other options not relevant for this case, such as Byline. However, Escobar and Demeritt (2012) had already established that using the headline missed substantial data and preferred searching "Anywhere in the text". After a testing a number of search terms on a case study of the victim of the summer 2012 floods in Shropshire, the following set of search terms was selected as the most efficient:
The first part of the search protocol specified the location of the fatality as within the UK. This sought to minimise false positives generated in trial searches that provided a large number of articles describing weather fatalities in other countries. This approach did not avoid a large number of results reporting on New England events, or on other foreign hazards where the UK government had sent aid or made a statement. However, a large number of reports on significant mortalities in places like Pakistan and the United States were filtered out in this way.

Weather hazards were defined as meteorological and hydrological events, with “storm” and “flood” considered, as well as colloquially used extreme weather terms like “gale” and “blizzard”. “Rain” and “snow” were excluded to focus the search on more extreme events. “Weather” was an umbrella term included to avoid false negatives which use other nouns to describe the event. All these terms were searched within roughly the same paragraph as the terms depicting death to improve the relevance of the results i.e. reduce the number of articles reporting on indirect deaths.

The wildcard character “!” was included to search for words with a variety of endings and conjugations. The term “casualt!” was problematic as it generated many false positives, where non-fatal casualties were mentioned. However, false positives were more generally a problem with the terms for death, as many articles included phrases like “without casualties” or “no one died”.

The relevance factor of the results generated was low, ranging between 4% and 16% for a given month’s total corpus of downloaded articles. Nevertheless, trial searches showed that no exclusionary terms (AND NOT terms) or further search words would significantly reduce the irrelevant results. Using AND instead of OR operators could reduce the number of articles generated, but the risk of false negatives, missing significant news stories, was judged to be too significant.
3.3.3 Applying the search terms to obtain corpus of articles

The search terms were applied on a month-by-month basis going back in time from December 2014 to January 2000. Individual searches were performed on a month by month basis. Apart from the January of each year, the search was specified as going from the second of each month to the first of each following month. This accounted for 30, 31, 28, and 29 day months without searching the same day twice. In total 180 individual searches were run with the same Boolean search terms within the LexisNexis Power Search tool. This ensured consistency of the method.

![Power Search](image)

**Figure 3.3-2 Example of a search run for April 2010.**

For consistency, the Boolean search protocol was copied and pasted from a master file, with only the dates changed every time.

The automatic exclusion of duplicate results (e.g. the same article from the morning and evening edition of a paper) feature was applied to each search; however, some duplicates and near-duplicates had to be filtered out manually.

In total, the search returned 33,000 articles, with an average of 2,200 articles per year. There was a observable increase in numbers of articles per year during the period, with 2013 returning the greatest number of articles, as can be seen from Table 3.3-1.

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1 Note the absence of quotation marks and parentheses in the main body of the search protocol, which was noted by the upgrade panel as unusual. In the trial searches, different combinations of Boolean modifiers were used. It was found that the addition of quotation marks and parentheses did not modify the returned results for these search terms, with the OR and AND operators driving most of the output. Some unnecessary articles could have been filtered out using parentheses around countries, for example, but trial searches showed that this reduction (less than 10%) was not overall significant enough to re-run the searches, given the efficiency of screening methods used later in the process.
Table 3.3-1 Total number of articles returned per month by the search protocol.
Deeper red shades show an increasing number of articles each year. This is mostly attributable to a greater number of digitised and printed news sources towards the later part of the study period. Medium blue represents monthly totals above the average, deep blue shows the top 10% of article monthly totals. July 2007 is highlighted, which coincides with the major flooding across England that summer. October 2013 – March 2014 is the busiest time for weather hazard reporting, which is in part attributable to the winter 2013-14 flooding in the West of the UK.

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<td>137</td>
<td>132</td>
<td>121</td>
<td>142</td>
<td>93</td>
<td>132</td>
</tr>
<tr>
<td>Total</td>
<td>3994</td>
<td>4486</td>
<td>2948</td>
<td>2493</td>
<td>2564</td>
<td>2203</td>
<td>2024</td>
<td>2447</td>
<td>1560</td>
<td>1701</td>
<td>1390</td>
<td>1303</td>
<td>1572</td>
<td>1101</td>
<td>1214</td>
</tr>
</tbody>
</table>

3.3.4 Downloading and cleaning the data
The results generated were downloaded as Microsoft Word files in .rtf format with contents lists, which is an option with the LexisNexis® Power Search tool. Each search was downloaded separately, creating separate documents for each month of each year. Months returning 500 articles and more had to be downloaded in two parts.

Figure 3.3-3 Example of downloaded corpus of articles for May 2014.
The clickable table of contents summarises the metadata for each individual article. The search terms were repeated in each document.
The contents lists were pasted as values into a spreadsheet template, with a separate worksheet for each month, and a separate workbook for each year. The spreadsheets featured a metadata section where the hyperlink to the search results and the file could be stored.

![Spreadsheet template](image)

Figure 3.3.4 Example of a month’s worth of article headlines for January 2010.

The articles were given a reference number comprised of the year and month of the search that returned them, e.g. 201001, and the serial number of the article in the results, starting from 001. It should be noted that the articles were returned in reverse chronological order, with the latest monthly reports at the top of the results, hence the first articles in the January 2010 set are from 1st February (first of every next month included in the search to account for different month lengths). This was later reconciled in the master database, but the article reference numbers have a reverse chronology.

The most labour intensive part of the process was coding the article headlines for relevance. In the exploratory phase, several search automated filters in excel and a python parser were considered to speed up the process. However, comparing the accuracy of the relevance filter to a manual operation always showed the superiority of the manual approach. With the Power Search tool already filtering out a great number of articles, any automation attempted on top of that either lost relevant results, or continued to return false positives.

The manual screening process involved three tests of the headline for relevance:

1. The headline mentions a weather event OR
2. The headline mentions a death or multiple deaths AND
3. The headline does not refer to a country that is not the UK

Following this set of tests, relevant articles were coded as 1 and irrelevant ones as 0.
Usually, relevance could be judged from the headline of the article, and coded as “1” or “0”; for unclear records, the full article could be consulted in the text document. This included headlines that referred to a weather event, but not to any casualties; in the full article the search terms were highlighted, which allowed for a quick judgement of whether a death was mentioned.

A second stage of coding for relevance involved grouping articles which clearly reported on the same death and incident. The relevant articles were filtered, and where adjacent articles clearly reported on the same incident, for example articles 1 – 4 from Figure 3.3-4 above, only the most complete (longest) articles were kept as 1 = relevant. So where article 4 reports that three people died, but articles 1-3 report that four people died, article 1 is downgraded to irrelevant as he others clearly have more complete and corroborated information.

With high numbers of false positives, the overall degree of relevance of the database was low. From the 33,000 headlines skimmed, only 1689 were coded as relevant, with an average relevance degree of 5% for each year’s corpus of articles.

**Table 3.3-2 Relevant articles in the search results.**

The relevance degree each month as an average of 5%. Relevant article outputs increased proportionately to the increase in the corpus of articles overall. The exception to this was 2012, which returned many articles relevant to weather fatalities, especially in the autumn of that year, which coincided with one of the wettest periods in the UK for 50 years (MetOffice, 2018a).

<table>
<thead>
<tr>
<th>Year</th>
<th>Articles per year</th>
<th>Relevant articles</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1214</td>
<td>85</td>
<td>7%</td>
</tr>
<tr>
<td>2001</td>
<td>1101</td>
<td>29</td>
<td>3%</td>
</tr>
<tr>
<td>2002</td>
<td>1572</td>
<td>109</td>
<td>7%</td>
</tr>
<tr>
<td>2003</td>
<td>1303</td>
<td>49</td>
<td>4%</td>
</tr>
<tr>
<td>2004</td>
<td>1390</td>
<td>63</td>
<td>5%</td>
</tr>
<tr>
<td>2005</td>
<td>1701</td>
<td>151</td>
<td>9%</td>
</tr>
<tr>
<td>2006</td>
<td>1560</td>
<td>109</td>
<td>7%</td>
</tr>
<tr>
<td>2007</td>
<td>2447</td>
<td>126</td>
<td>5%</td>
</tr>
<tr>
<td>2008</td>
<td>2024</td>
<td>71</td>
<td>4%</td>
</tr>
<tr>
<td>2009</td>
<td>2203</td>
<td>35</td>
<td>2%</td>
</tr>
<tr>
<td>2010</td>
<td>2564</td>
<td>38</td>
<td>1%</td>
</tr>
<tr>
<td>2011</td>
<td>2493</td>
<td>66</td>
<td>3%</td>
</tr>
<tr>
<td>2012</td>
<td>2948</td>
<td>461</td>
<td>16%</td>
</tr>
<tr>
<td>2013</td>
<td>4486</td>
<td>181</td>
<td>4%</td>
</tr>
<tr>
<td>2014</td>
<td>3994</td>
<td>116</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>33000</td>
<td>1689</td>
<td></td>
</tr>
</tbody>
</table>
3.3.5 Identifying a relevant article, extracting and coding its information

Having established a corpus of relevant articles, the analysis went back to the original text files to extract and code information about each victim. This involved cross referencing article numbers and reading through the most relevant articles for each case. The Power Search tool highlights the search terms in the downloaded documents, so articles were easy to skim for relevant contextual information.

Figure 3.3-5 Example of full article 201303.118 with the search terms highlighted.

The example shows that the search terms highlighted one relevant death (Olivia – blown into the path of a lorry by stormy winds), one irrelevant death (Jamie Bell – secondary death, could be unrelated to the cold), and one avoided fatality (Massey family evacuated), whilst failing to highlight another relevant fatality (Susan Norman crushed by landslip). This highlights the necessity of manually checking relevant articles and cross-referencing with others for a comprehensive dataset.

Where more than one article reported on a discrete fatality, the most relevant article was selected as the base source of contextual data. The most prolific casualties, either the most shocking cases or those picked up by the broadsheets could have up to 30 relevant articles describing the. However, most fatalities had relevant information in 3-4 articles, most of which was duplicated. So the most complete or latest article was taken as a base for the record, and the others were listed as auxiliary sources. Where more than one article would report on a discrete death, information from multiple articles was extracted, cross-referenced and coded within the list. Specific information extracted form, and the way in which it was recorded, is explained in the metadata description in Table 3.3-3. A screenshot of the basic database is provided for illustration in Table 3.3-5.
Table 3.3-4 Flood and extreme weather fatality metadata, extracted and recorded form the newspaper reports.
The data recorded included a combination of nominal and categorical data, as well as free-text descriptive parameters, quoted or inferred from the article content. Categorical data included derived categories, like gender (meaning gender expression, as reported by the article), and inferred and coded categories, like causal weather hazard.

<table>
<thead>
<tr>
<th>Data Extracted</th>
<th>Description</th>
<th>Notes</th>
<th>Coverage: [All hazards]; [flood fatalities]</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Article reference</td>
<td>Reference for the article, including the year, month, and serial number in the results spreadsheet.</td>
<td>The reference article for each fatality was chosen as the longest or latest article, whichever provided the most information.</td>
<td>All records</td>
<td>201312.097</td>
</tr>
<tr>
<td>Year</td>
<td>Year of event and the death.</td>
<td>Coincides with year of publication, the first four digits of the article reference, and the first two digits of the victim ID.</td>
<td>All records</td>
<td>2013</td>
</tr>
<tr>
<td>Month</td>
<td>Month in which the event and death occurred.</td>
<td>This was not always the same as the month of publication, for example if an article on the first of the month was describing the previous month’s events. Occasionally, the most relevant (fullest information) article was a review article, taking an historic view about the previous month’s or summer’s floods. Precise dates of death were coded at a later stage for a subset of flood fatalities. They were not simple to capture because reporting was not immediate, and often reflective, whilst events themselves could span a number of days and a date was difficult to attribute. This is further described in Chapter 5.1.</td>
<td>All records</td>
<td>Dec</td>
</tr>
<tr>
<td>Victim ID</td>
<td>A serial ID, including the month, year and cumulative number of the victim reported within that month.</td>
<td>If the report was about the third person reported to have died that month, the last two digits would be 03.</td>
<td>All records</td>
<td>13.12.02</td>
</tr>
<tr>
<td>Name</td>
<td>Name and surname of the victim, where available.</td>
<td>Having the name and surname made it much easier to validate the corpus of articles with other online news sources through search engine queries.</td>
<td>64%; 75%</td>
<td>Nick Mutton</td>
</tr>
<tr>
<td>Age</td>
<td>Age of the victim, where available.</td>
<td>The age informed the analysis of contextual vulnerability.</td>
<td>87%; 97%</td>
<td>46</td>
</tr>
<tr>
<td>Data Extracted</td>
<td>Description</td>
<td>Notes</td>
<td>Coverage:</td>
<td>Example</td>
</tr>
<tr>
<td>----------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Gender</td>
<td>Gender (expression) of the victim, as reported, coded as “M” or “F”.</td>
<td>Gender was the most ubiquitously reported detail.</td>
<td>96%; 100%</td>
<td>M</td>
</tr>
<tr>
<td>Occupation / Background</td>
<td>Occupation, education or other background details, where reported. Data here included: - professions e.g. teacher, lorry driver; - trades e.g. joiner; - pastimes which could shed light on the circumstance of fatality e.g. angler, amateur athlete; - past profession, which could suggest an economic strata e.g. retired judge, retired company director; - dependence or independence state, e.g. student, schoolboy, grandchild</td>
<td>This could be inferred into a socio-demographic profile of the victim, if enough details were available. None of this data could be quantitatively analysed due to its reported nature, inconsistent typology, and low reporting rates – background data was reported for fewer than half of the victims. Where backgrounds were described, this was un stories which appeared across multiple articles, with journalists gathering a casualty profile over time: it could be observed that later reports had more of these details. Therefore, the data could be used to enrich case studies of specific fatalities and provide contextual information.</td>
<td>40%; 47%</td>
<td>Teacher</td>
</tr>
<tr>
<td>Hazard event</td>
<td>The type of weather hazard which caused the death. Coded as: - flood; - storm; - gale; or, - snow/ice.</td>
<td>This category required some interpretation.</td>
<td>All records</td>
<td>Flood</td>
</tr>
</tbody>
</table>
Chapter 3

Methodology: Gathering Fatality Data

<table>
<thead>
<tr>
<th>Data Extracted</th>
<th>Description</th>
<th>Notes</th>
<th>Coverage:</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>[All hazards]; [flood fatalities]</td>
<td></td>
</tr>
</tbody>
</table>

- Specifically mentioning flooding, and became a catchall term for deaths in “atrocious weather” or similar description, when a hazards could not be directly attributed.

- **Snow/ice** was the attributed hazard for hypothermia deaths where freezing weather was reported, and included deaths from falling into frozen or icy (but not flooded) waterbodies. Only one hazard was attributed to each fatality. Where multiple hazards could have been causal, judgement was exercised to select the most likely, cross-referencing with other possible records in online sources. Flood fatalities were scrutinised carefully across multiple sources. Where gale or storm were unclear, storm was chosen as the causal hazard.

- **Cause of death** A descriptive parameter, quoting or paraphrasing the article to describe the situation at the time of death.
  - This was a situational contextual parameter, although most deaths could be coded as hypothermia, asphyxiations, or blunt trauma. Instead, the category provided a context of the deaths to enrich a case by case analysis.
  - All records
  - drowned in swollen river, attempted dog rescue

- **Activity at the time** Basic summary of activity at the time of the incident which led to the fatality. A free text parameter, but common categories included: driving (driver or passenger), walking (recreational-, dog-, hill-), climbing, water sports (sailing, canoeing, kayaking, swimming), spending time at home.
  - This parameter was looking to distinguish between work, travel, and recreational activities.
  - 88%; 80%

- **Location** A geographical descriptor, as detailed as reported. Ranging from road and village level, to county level. For flood deaths, on occasion the river or tributary was reported.
  - Some level of location data was reported for all records, but this varied greatly in scale. More precise geolocation was not attempted at this stage, but was added later specifically for flood fatalities, as described in chapter 6.1.
  - All records
  - Newton Abbot, Devon
### Methodology: Gathering Fatality Data

#### Data Extracted

<table>
<thead>
<tr>
<th>Coverage:</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>[All hazards]; [flood fatalities]</td>
<td>outdoors</td>
</tr>
</tbody>
</table>

#### Description

- **Road, home, outdoors**: An analysis of where the fatality occurred, coded as “indoors”, “outdoors”, and “road”. This was used for the contextual vulnerability analysis and is further described in 7.3. Road fatalities always involved vehicles: usually the casualties were driving or were killed by a vehicle as a result of hazardous weather. The indoor category covered victims who died inside buildings, primarily homes, but also places of work or recreation. All outdoor, non-vehicle related deaths were coded as having occurred “outdoors”.

- **Vulnerable, risk taker**: A high-level analysis of the victim’s contextual vulnerability and behaviour. Coded as “vulnerable”, “risk taker”, or “unknown”. Most cases were coded as of an “unknown” level of vulnerability or type of behaviour. Victims under 18 and over 70 years of age were coded as “vulnerable” based on that basic information. Where enough contextual data was provided in the articles about the activity at the time, a judgement was made. Those victims who were engaging in extreme outdoor activities at the time (e.g. mountain climbing) were coded as “risk takers”. Where victims were both vulnerable by age and taking a risk, “risk taker” was the assigned category. This interpretation is further described in Chapter 7.

#### Notes

- **Vulnerable, risk taker**: Most cases were coded as of an “unknown” level of vulnerability or type of behaviour. Victims under 18 and over 70 years of age were coded as “vulnerable” based on that basic information. Where enough contextual data was provided in the articles about the activity at the time, a judgement was made. Those victims who were engaging in extreme outdoor activities at the time (e.g. mountain climbing) were coded as “risk takers”. Where victims were both vulnerable by age and taking a risk, “risk taker” was the assigned category. This interpretation is further described in Chapter 7.

#### Table 3.3-5 An extract of the weather fatalities database for casualties in 2014.

The database was created in Excel, with .csv versions imported into SPSS, QGIS, and Docparser for further analysis. Additional columns were added for subsequent analysis, and the flood hazard casualties were extracted as a separate database for the purposes of data visualisation.

<table>
<thead>
<tr>
<th>Article reference</th>
<th>Year</th>
<th>Month</th>
<th>Victim</th>
<th>Name</th>
<th>Age</th>
<th>Gender</th>
<th>Occupation/Background</th>
<th>Hazard event</th>
<th>Cause of death</th>
<th>Activity at the time</th>
<th>Location</th>
<th>Road, home, outdoors</th>
<th>Vulnerable, risk taker</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014.01.283</td>
<td>2014</td>
<td>Jan</td>
<td>14.01.01</td>
<td>Henry Soward</td>
<td>27</td>
<td>M</td>
<td>teaching assistant</td>
<td>storm</td>
<td>dropped out to sea by huge wave</td>
<td>paddling with friends in Lee Bar, Cornwall</td>
<td>outdoors</td>
<td>risk taker</td>
<td></td>
</tr>
<tr>
<td>2014.01.371</td>
<td>2014</td>
<td>Jan</td>
<td>14.01.05</td>
<td>unknown</td>
<td>47</td>
<td>M</td>
<td>unknown</td>
<td>flood</td>
<td>mobility scooter fell into the river from a flood</td>
<td>unknown</td>
<td>Oxford</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>2014.01.211</td>
<td>2014</td>
<td>Jan</td>
<td>14.01.08</td>
<td>Harry Martin</td>
<td>18</td>
<td>M</td>
<td>student</td>
<td>storm</td>
<td>drowned in storm</td>
<td>photographing storm</td>
<td>Newton Ferrers, Devon</td>
<td>outdoors</td>
<td>risk taker</td>
</tr>
<tr>
<td>2014.02.214</td>
<td>2014</td>
<td>Feb</td>
<td>14.02.01</td>
<td>Julia Sillitoe</td>
<td>49</td>
<td>F</td>
<td>minicab driver</td>
<td>gale</td>
<td>crashed by masonry blown from building due to driving</td>
<td>London</td>
<td>road</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>2014.02.247</td>
<td>2014</td>
<td>Feb</td>
<td>14.02.02</td>
<td>unknown</td>
<td>77</td>
<td>M</td>
<td>unknown</td>
<td>gale</td>
<td>hit by falling tree</td>
<td>unknown</td>
<td>Caernarfon, North Wales</td>
<td>outdoors</td>
<td>vulnerable</td>
</tr>
<tr>
<td>2014.02.247</td>
<td>2014</td>
<td>Feb</td>
<td>14.02.03</td>
<td>Roger Haywood</td>
<td>71</td>
<td>M</td>
<td>unknown</td>
<td>gale</td>
<td>electrocuted by fallen power lines</td>
<td>clearing fallen trees in Brenhill, Wiltshire</td>
<td>outdoors</td>
<td>risk taker</td>
<td></td>
</tr>
<tr>
<td>2014.02.247</td>
<td>2014</td>
<td>Feb</td>
<td>14.02.04</td>
<td>Gartheth Lockyer</td>
<td>34</td>
<td>M</td>
<td>unknown</td>
<td>storm</td>
<td>drowned in swollen river</td>
<td>kayaking</td>
<td>Crickhowell, South Wales</td>
<td>outdoors</td>
<td>risk taker</td>
</tr>
<tr>
<td>2014.02.247</td>
<td>2014</td>
<td>Feb</td>
<td>14.02.05</td>
<td>Zane Grangbula</td>
<td>7</td>
<td>M</td>
<td>unknown</td>
<td>flood</td>
<td>CO poisoning from flood pump</td>
<td>sleeping</td>
<td>Chersey, Surrey</td>
<td>home</td>
<td>vulnerable</td>
</tr>
<tr>
<td>2014.02.527</td>
<td>2014</td>
<td>Feb</td>
<td>14.02.06</td>
<td>unknown</td>
<td>73</td>
<td>M</td>
<td>unknown</td>
<td>gale</td>
<td>critically injured after being trapped by fallen</td>
<td>unknown</td>
<td>Co Tyrone, Northern Ire</td>
<td>outdoors</td>
<td>vulnerable</td>
</tr>
<tr>
<td>2014.18.109</td>
<td>2014</td>
<td>Oct</td>
<td>14.10.01</td>
<td>Tarwita Sion</td>
<td>58</td>
<td>F</td>
<td>nanny</td>
<td>gale</td>
<td>crushed by falling tree which should have been walking</td>
<td>London</td>
<td>outdoors</td>
<td>unknown</td>
<td></td>
</tr>
<tr>
<td>2014.18.099</td>
<td>2014</td>
<td>Oct</td>
<td>14.10.02</td>
<td>Scott Powell</td>
<td>30</td>
<td>M</td>
<td>builder</td>
<td>gale</td>
<td>crushed by van as jack collapsed in high winds</td>
<td>working on his van</td>
<td>Canvey Island, Essex</td>
<td>outdoors</td>
<td>risk taker</td>
</tr>
<tr>
<td>2014.18.296</td>
<td>2014</td>
<td>Oct</td>
<td>14.10.03</td>
<td>unknown</td>
<td>61</td>
<td>M</td>
<td>taxi driver</td>
<td>gale</td>
<td>hit by falling masonry</td>
<td>walking</td>
<td>Bridlington, Yorkshire</td>
<td>outdoors</td>
<td>unknown</td>
</tr>
</tbody>
</table>
3.3.5.1 Inclusion and exclusion criteria

The fatalities stories extracted were screened for relevance using the test: **would they have happened under different weather conditions?** As such, the most direct fatal outcomes of hazards were noted and the deaths usually happened within the time of the hazard impact. Further, only deaths occurring in extreme weather were recorded; instances reporting heavy rain or rough seas were not included. The extremity of the weather was judged in a qualitative way, but as Chapter 8 will show, the intersection of incidents with severe weather warnings was quite high.

Heatwave and cold weather deaths were excluded from the study. These deaths are multiple and a subject of vast amounts of epidemiological research. As they can be exacerbated by underlying medical conditions, it is difficult to delineate weather as a key cause of death.

**Table 3.3-6** lists the some types of fatal circumstances encountered in the data which required a test of judgement call, and how they were dealt with in accordance to the inclusion/exclusion test: would this situation have been fatal under different weather conditions? An initial list of causes was created prior to data gathering, but the list was built upon and added to during the process. Road deaths presented the greatest challenge – how to interpret driving errors and their exacerbation in extreme weather. After several trial methods, where the inclusion of a road death was unclear, it was included in a separate auxiliary list of road fatalities, which added contextual information to included road deaths, but did not affect the totals.

**Table 3.3-6 Inclusion and exclusion of fatality records – list of common cases.**
The list of inclusion and exclusion criteria was prepared and then iteratively build upon during the data gathering process as new circumstances were found.

<table>
<thead>
<tr>
<th>Circumstance of fatality</th>
<th>Include?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dying in flood water</strong></td>
<td></td>
</tr>
<tr>
<td>Hypothermia from being in flood water for too long</td>
<td>Yes</td>
</tr>
<tr>
<td>Asphyxiation or hypothermia in flood water breaching premises</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Accidents while hill walking/ mountain climbing</strong></td>
<td></td>
</tr>
<tr>
<td>bad weather, no details mentioned</td>
<td>No</td>
</tr>
<tr>
<td>poor visibility</td>
<td>No</td>
</tr>
<tr>
<td>storm, blizzard, or gale mentioned</td>
<td>Yes</td>
</tr>
<tr>
<td>avalanche during poor weather conditions</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Accidents while walking outside</strong></td>
<td></td>
</tr>
<tr>
<td>cliff falls after slipping on sodden ground after storm reports</td>
<td>Yes</td>
</tr>
<tr>
<td>slipping into swollen watercourses</td>
<td>Yes</td>
</tr>
</tbody>
</table>
### Circumstance of fatality

<table>
<thead>
<tr>
<th>Circumstance of fatality</th>
<th>Include?</th>
</tr>
</thead>
<tbody>
<tr>
<td>washed off shore by huge waves</td>
<td>Yes</td>
</tr>
<tr>
<td>overcome by water whilst crossing a field, etc.</td>
<td>Yes</td>
</tr>
<tr>
<td>slipping and falling on ice</td>
<td>No</td>
</tr>
<tr>
<td>Blunt trauma from wind-dislodged masonry, trees, etc.</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Secondary deaths**

<table>
<thead>
<tr>
<th>Circumstance of fatality</th>
<th>Include?</th>
</tr>
</thead>
<tbody>
<tr>
<td>asphyxiation from fumes from flood pump</td>
<td>Yes</td>
</tr>
<tr>
<td>heart attack from lifting sand bags during flood</td>
<td>Yes</td>
</tr>
<tr>
<td>premature birth due to flood compounded stress</td>
<td>No</td>
</tr>
<tr>
<td>virus from ingested floodwater</td>
<td>No</td>
</tr>
<tr>
<td>crushed in house which collapsed in landslip after flood</td>
<td>Yes</td>
</tr>
<tr>
<td>run over by bulldozer installing flood defences</td>
<td>No</td>
</tr>
<tr>
<td>death from injury: being struck with objects blown away by storms</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Road accidents**

<table>
<thead>
<tr>
<th>Circumstance of fatality</th>
<th>Include?</th>
</tr>
</thead>
<tbody>
<tr>
<td>car inundated with water</td>
<td>Yes</td>
</tr>
<tr>
<td>car stuck in water</td>
<td>Yes</td>
</tr>
<tr>
<td>car blown over in cross-wind</td>
<td>Yes</td>
</tr>
<tr>
<td>collision in bad weather conditions</td>
<td>No</td>
</tr>
<tr>
<td>aquaplaning or skidding in poor weather</td>
<td>No</td>
</tr>
<tr>
<td>loss of control in poor weather</td>
<td>No</td>
</tr>
<tr>
<td>run over by car in a snow storm</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Water sports accidents**

<table>
<thead>
<tr>
<th>Circumstance of fatality</th>
<th>Include?</th>
</tr>
</thead>
<tbody>
<tr>
<td>trouble during recreational swimming in poor weather conditions</td>
<td>No</td>
</tr>
<tr>
<td>drowning while surfing, kayaking, canoeing in storm/flood</td>
<td>Yes</td>
</tr>
<tr>
<td>commercial sailing in storm conditions</td>
<td>No</td>
</tr>
<tr>
<td>private/recreational sailing in storm conditions</td>
<td>Yes</td>
</tr>
<tr>
<td>drowning whilst swimming in a heatwave</td>
<td>No</td>
</tr>
<tr>
<td>drowning whilst swimming in swollen river courses in storm/flood</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Snow deaths**

<table>
<thead>
<tr>
<th>Circumstance of fatality</th>
<th>Include?</th>
</tr>
</thead>
<tbody>
<tr>
<td>hypothermia in extreme cold whilst out, if snow storm or blizzard</td>
<td>Yes</td>
</tr>
<tr>
<td>hypothermia due to moderate cold (no snow storm)</td>
<td>No</td>
</tr>
<tr>
<td>sledding accident</td>
<td>No</td>
</tr>
<tr>
<td>crushed by snow</td>
<td>No</td>
</tr>
<tr>
<td>hypothermia after falling through ice into cold water</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 3.3.6 Quality checking and improving the data: collation, triangulation, additional data

The assembled corpus of fatalities was checked by examining whether each individual death record was in fact in scope. Where data was missing, the corpus of articles was consulted to see whether different records had mentioned further details. Additional relevant article reference numbers were added as notes to the fatality record. Some records included additional information from up to four discrete articles. However, in the majority of cases (about 80%), a single summarising article was the source of all the parameters.
For specific cases of flood fatalities, where the context of situation was especially illustrative of a particular trend, or served to become a vignette to illustrate the following chapters, additional sources were consulted by search engine queries using the victim’s name, year of death, and location. This usually returned additional information from online news sites, most often BBC news, as well as subsequent retrospective news articles published later than the study period end in 2014.

From the articles, there is a marked difference in data richness between flood fatalities and other hazards. Flood cases often include a lot more contextual information, comments from local people or family members, details on the victim’s background. This sort of contextual richness is almost completely absent from gale hazard deaths from falling objects, for example, and much less evident in most deaths on the road, unless the victims in the vehicle were multiple or involved children. The assumption here is that the degree of sensationalism around specific hazards affects their saliency for news reports. Most gale deaths are closer to tragic accidents than natural hazard impacts, and therefore much less “reportable” for journalists. Any deaths involving children or prominent people in local communities carry a lot of contextual detail, because they cause more shock and attract a lot of commentators.

In light of these differences, it can be said with some confidence, that the data quality for flood fatalities is the superior subset of the database. This supports the study design, wherein most of the analysis is conducted on flood fatality data, with other weather hazard deaths providing a basis for an illustrative high level comparison.

In the case of flood deaths, the consistency and robustness of the search protocol was tested and confirmed by running it again for specific months which represented significant events or death tolls where other impact datasets were available, for example July 2007 flooding where impacts, including fatalities, are well documented (Pitt, 2008). With a relatively small dataset of flood fatalities, it was easy to check through each record, going back to the corpus of newspapers, triangulating with online data sources, and generally improving the quality of the records.

Additional data parameters were added for specific parts of the analysis, which will be described in more detail in the analytical chapters. For Chapter 5, flood deaths were analysed to identify the
flooded water courses which were causal to the incident, and the region of the UK in which they were located. This was done by gathering as much location data from the articles as possible and using river drainage maps to get a qualitative impression of the nearest body of water, categorising it by region: South West England, South East, Central, North East, North West and Wales or Scotland.

For Chapter 6 each flood fatality was assigned a coordinate reference based on the best location information available in the article. This was done by using gridreferencefinder.com, entering the best available location information and surveying the map for the most likely point of death by triangulating nearby water courses which may have flooded. Unfortunately, the location information in the article varies widely from the mention of a county to the specific street address, and this is further complicated by the fact that it is hard to say where a person would have fallen into the water, versus where their body was found. The chapter provides more detail on this methodology.

For Chapter 8, the date information was improved upon for flood and gale deaths. The individual articles were re-examined to find the most likely date of death, either from the context of from using the publication date minus one/two days. More details on this method are described in the chapter.

The resulting corpus of fatality records is a rich and carefully collated dataset, which can be used for further analysis or extended to a wider study period.

### 3.4 Limits to the method

The reliability of the data is uncertain. Although more incidents have been identified than in any official report, the accuracy of information on each incident is difficult to verify. Reporters will use the same sources for stories and information can get lost or distorted in the editing process.

This study assumes that fatalities are rare and significant enough to be reported in the press, at least at the local level. Although this is supported by the data – each death is reported in more than one article – this does not prove that there are no unreported casualties. This limitation can be addressed by cross-referencing the counted fatalities with official death statistics and coroners’ reports; however, the abovementioned issue of classification within these sources will be a further complication.
The lack of follow-up in reports provides another limitation and generates potential false negatives. Several victims have been reported as “feared dead” or missing without subsequent confirmation of either rescue or death. These cases may have to be followed up individually through coroners’ reports, but any such research will be subject to confidentiality restrictions, as victims would have to be searched for by name.

The Boolean search parameters which were used to trawl LexisNexis® were carefully designed and pilot tested. However, the definitions of hazards may have been reductive in so far as to miss particular fatalities, for example deaths in extreme rainfall, but not as a result of flooding.

The search protocol also generated thousands of false positives: articles which included the search terms but were not relevant. These false positives were of two kinds. The first came from lexical ambiguities including the metaphorical use of the term “flood”, which were often associated with articles about deaths e.g. “messages of condolence flooding in”, “floods of tears”. The second type of false positive was geographical: reports of fatal floods and storms in other countries came up if the by-line of the article specified that it came from a Scottish or Welsh publication i.e. the country search term was satisfied by unnecessary data.

Another limitation was the lack of consistency in the level of detail reported on each fatality. Some reports could include a full profile of the victim, with quotes by members of their family, whilst others would mention that “a man died in Nottingham as a result of yesterday’s storm”. In many cases these data gaps could be filled by looking at adjacent articles, but overall missing data meant that like for like analysis of the records was hindered. For example, no age was reported for several flood fatalities, meaning an average fatality age could be skewed if all of the unknowns were in fact of a similar age to each other.

3.5 Conclusion: detailed and comprehensive fatality data

Despite its limitations, the method was successful in identifying a corpus of 33,000 matching articles, and reducing it to a database of several hundred relevant reports. These were then carefully read and reviewed to extract and code relevant data on all extreme weather fatalities in the UK from 2000 – 2014. The method was also replicable, as on several occasions articles were
downloaded repeatedly to check for consistency – similar numbers were returned each time. The strength of the method lies in its combination of the best aspects of existing flood fatality data sources. It takes a high-level view of all hazard impact databases but looking at total deaths over a period of time, which provides the opportunity for analysing multiple events and tracing trends over time. At the same time, by using the richness of newspaper sources, the database reflects the detailed qualitative information explored by case-study analyses of fatal impacts of flood events.
“At that moment Maggie felt a startling sensation of sudden cold
about her knees and feet; it was water flowing under her. She
started up; the stream was flowing under the door that led into the
passage. She was not bewildered for an instant; she knew it was
the flood!”

“The Mill on the Floss”, George Eliot, 1860

Much like George Eliot's description of the rapidly bursting banks of the fictional Lincolnshire river Ripple, floods enter our imagination in a dramatic and cataclysmic way. Maggie Tulliver's experience of the flood in the novel is of a short and tragic escape and rescue attempt, that happens quickly and unfolds in chaotic darkness. The victims are young and able bodied, with shorter flood memories than the older residents of the village, but with sufficient knowledge of what to do in an emergency – they are resourceful, waste no time and apply themselves fully to mitigating risks. Their eventual demise is largely Eliot's literary device of ridding the book of its fallen heroine, who cannot overcome the societal exile imposed on her, but the dramatic, biblical extent of the flood in book's final scene resonates with the reader’s imagination of a major hazardous event and its perils.

One of the main aims of the flood fatalities investigation has been to see whether our expectations and understandings of flood victims and their circumstances are supported by real evidence of direct flood death. Literary representations of dramatic flood impact are rarely repeated in real UK weather events. An event of the magnitude of the Riddle flood is a low frequency event: the novel hints at a return rate of 40 or 50 years. More often in the UK, it is the cumulative impacts of smaller events that cause the greatest levels of destruction. The 2007 summer floods were an example of a devastating event, with Gloucestershire the most severely affected county. The government commissioned an independent review of lessons learnt from the 2007 floods, which quoted Chief Constable Tim Brain summarising: “In terms of scale, complexity and duration, this is simply the largest peacetime emergency we’ve seen” (Pitt 2008, p. ix). Arguably the greatest impact came from the loss of critical infrastructure after the inundation of an electricity substation and a water
treatment plant: this left 42,000 people without power and 350,000 without a water supply. Critical national assets were at risk of major disruption, including GCHQ – the government’s electronic intelligence agency – which had to suspend non-critical operations at its base in Cheltenham. Whilst 55,000 properties were flooded nationwide in a series of intense flood events in various geographies, July 2007 reports only four flood related deaths, two of them in the same incident.

A forty-year-old man drowned in the swollen river Ouse near Bedford whilst attempting to cross it on a walk; in Tewkesbury a father (64) and son (27) were asphyxiated by flood pump fumes as they attempted to clear the cellar of their local rugby club; and, also in Tewkesbury a 19-year-old barman drowned in rapidly rising flood waters on his return from a night out. In a fascinating way the circumstances of the four deaths resonate with the cataclysmic demise of George Eliot’s characters: they were partially aware of the flood, though possibly surprised by its ferocity; they are all able bodied and active with a mean age of 38; the first three are actively trying to overcome the perilous conditions, only the fourth is overwhelmed by the hazard; and, in a similar way, the first three deaths have some knowledge of flood circumstances and behaviour. However, in an ex ante assessment, these men would have been unlikely to flag up as vulnerable; they are four unlikely victims, if models of vulnerability explored in Chapter 2 are to be used as a starting point.

Floods and other extreme weather events are emotive subjects, which capture the public imagination - and hence the attention of policy makers – as elemental, rapid, chaotic and perilous events, endangering the lives of all who live in their path. Theory, on the other hand, teaches us that hazards are discriminatory, endangering clear sectors of the population more than others along the fissures of contextual vulnerability. However, in practice we have no solid data on the profile of a typical flood casualty in the UK and the circumstances of their death. The database developed as part of this research project can begin to shed light on the nature of the death toll in actuality for a fragment of time for the UK.

The database was developed in a context of a wider literature on flood death, and therefore it looked for and reports specific categories of data, which will help establish the practical application of ideas in this area. Jonkman and Kelman (2005) identified that a number of flood deaths could be attributed to the unnecessary risk taking behaviour of male victims. Building on this, the database reports the
gender of the victims where available and draws together wider contextual information about each fatality to suggest whether the casualty took a risk or not.

In her analysis of the 2002 floods in Gard, Southern France, Ruin et al. (2008) identifies an inverse relationship between catchment size and risk, whilst factoring in the exposure of the victims: a national level assessment using newspaper records makes catchment categorisation very uncertain, the database does differentiate between deaths in watercourses and elsewhere, while categorising exposure based on the victims’ location – indoors, outdoors, or on the road (in vehicles).

Further conclusions of road and vehicle deaths in flood conditions were made by Kellar and Schmidlin (2012) for the United States between 1995 and 2005, showing that men were predominantly the victims, with sharp rises in mortality observed at the extreme ends of the age scale. Consequently, the database results are scrutinised by age and gender both as independent and dependent variables.

The 1953 floods on the East coast of England claimed 307 lives, most of them in the estuary town of Canvey island. Here the waters rose rapidly at around 1.30 AM, when most victims were unaware and asleep in their homes (Wicks, 2013). The indoor location of victims was the key exacerbating factor of fatality impact, and with this in mind, the analysis categorises deaths by their indoor-outdoor location. In strikingly similar circumstances, 41 people died in a sea surge on the French Atlantic coast during storm Xynthia in 2010: 29 victims died in one local area, three quarters of the victims were over 60 years old and three quarters died in single storey bungalows. The sea surged at night and the impact had not been forewarned by a Météo-France alert (Vinet et al., 2012). The converging factors of old age, coastal location, single storey structure, and a lack of warning are some of the reasons for significant vulnerabilities during this event. To reflect this, the study singles out deaths inside homes, focuses on elderly and frail casualties, and takes a careful look at flood warnings and their interaction with fatality statistics.

Ex-post surveys of people affected by the 1997 Red River flood in Manitoba (Buckland and Rahman, 1999), which killed 11 people, described the particular exposure and risk perception by different types of rural communities to the flood. Whilst 71% feared death in a flood context, many respondents to subsequent interviews felt that the issued evacuation order was inappropriate for
their location. To explore this further, the analysis distinguished between fatalities in urban and rural settings.

Recent analysis from the US (Terti et al. 2016) proves that the victim’s activity at the time of the fatal flood onset is a key determinant of the fatal outcome: in parallel the database reads carefully into the circumstances described in the newspaper reports, extracting both descriptive and categorical data.

Overall it can be said that analyses of hazard fatalities in the developed world are shifting away from vulnerability profiling as the main explanation. The database developed as part of this study supports this trend, proving that the majority of deaths from weather events in the UK since 2000 have not been amongst contextually vulnerable populations.

**The aim of this chapter**

The Chapter presents an introductory exploration of the fatalities database compiles for the purposes of this study. It’s main aim is to address the identified data gap: that there is no systematic dataset of deaths from floods in the UK. To illustrate the profile of flood casualties, the Chapter augments them with key figures for deaths from other weather hazards. The analysis builds towards addressing the first research question:

- Who is dying from flooding and other weather hazards in the UK?

It will address this question by analysing total aggregate numbers of casualties to test the hypothesis: “**Flood and other weather hazards in the UK lead to very low numbers of casualties, which do not follow any temporal patterns or historic trends.**” The analysis will include the following aggregate numbers:

- Fatalities form flood and other weather hazards in the UK for the study period;
- Their temporal trends: annual, seasonal, monthly;
- Their historic trends in the context of other studies;
- Hazard typology by total casualty numbers and types of fatal incident;
- UK weather hazard deaths in the context of UK mortality; and,
- UK weather hazard deaths compared to similar US statistics.

Overall, it will become evident that the most striking aspect of the generated data is that the numbers of deaths are low. The events which struck the UK in the period 2000 to 2014 did not have devastating loss of life impacts. The chapter will show that, apart from a spike in the summer of
2007, UK flood casualties are fairly rare and random in relation to the predictability of flood events. Further chapters will explore whether this can be attributed to their low magnitude or to the level of preparedness and resilience with which they were met. For now, we will look at the totals for the whole period and examine them in context.

### 4.1 Aggregate numbers of weather fatalities
The database condensed over 9,000 relevant newspaper reports into categorised incidents of flood and weather hazard fatality for the UK during the period 2000-2014. **Table 4.1-1** presents the aggregate annual totals for direct weather casualties.

<table>
<thead>
<tr>
<th>Year</th>
<th>All weather event fatalities</th>
<th>Deaths from flood events</th>
<th>Deaths from other weather hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>13</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2002</td>
<td>27</td>
<td>4</td>
<td>23</td>
</tr>
<tr>
<td>2003</td>
<td>5</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2004</td>
<td>10</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>2005</td>
<td>15</td>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>2006</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>2007</td>
<td>41</td>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>2008</td>
<td>14</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2009</td>
<td>23</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>2010</td>
<td>11</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>2011</td>
<td>12</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>2012</td>
<td>10</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>2013</td>
<td>19</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>2014</td>
<td>12</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>225</strong></td>
<td><strong>62</strong></td>
<td><strong>163</strong></td>
</tr>
</tbody>
</table>

The numbers of fatalities from flood events are low, fluctuating around a mean of 4.13 every year for the duration of the study period. One spike in flood death was observed in 2007, which can be attributed in part to the flooding in June and July, which affected a number of regions and led to ten casualties in total over the two-month period. The other reported casualties were usually single incidents per flood event, with five instances reporting two people dying together.
Other weather hazards, which include high winds, storms and blizzards, have a greater annual range for numbers of direct fatality. Storms or gales were found to cause multiple deaths and injuries in different locations. This is partly attributable to the fact that storm events generally have larger footprints than floods. However, as Figure 4.1-1 shows, the graph of deaths from non-flood weather hazards is noisy with fairly random spikes for certain years: 2002, 2007, 2009. Although this can be explained in part by specific high magnitude events, like the 2007 summer storms, the 2009 floods in November-December, and storm Jeanette in October 2002, there are other significant weather events which are not reflected as clearly by spikes in the graph, for example the St Jude’s day storm in October 2013, which accounts for five casualties, whereas December of the same year saw eight deaths from different hazards. Similarly, while there were several significant flood events in 2012, which caused severe disruption and significant property damage (April, June, August, November); there were relatively few casualties that year. Chapter 5 will examine why certain events or even entire calendar years are “safer” in terms of direct deaths from weather hazards; at this stage, it is important to stress that the aggregate numbers fail to tell the whole story.

**Figure 4.1-1 Number of fatalities – annual flood and other hazard fatalities 2000 – 2014:**
There is no obvious trend in fatalities over time. A notable spike in 2007 can be in part attributed to the severe June-July floods of that year. However, 2012 saw a number of high magnitude flood and storm events, yet fatalities were few. 2007 seems to skew the mean. Fatalities fluctuate around the median 12 deaths per year.
Looking at the aggregate fatality numbers more closely, we can see some patterns in the months for which the fatality is reported in Figure 4.1-2.

**Figure 4.1-2 Percentage of fatalities reported in each month for a) floods, and b) other hazards:**

Breakdown of month of death for flood fatalities and other weather hazard (not including flood) fatalities. For floods, there is a clear seasonal pattern, with more deaths occurring in the summer and winter months. For other weather hazards, the winter months are more hazardous, with January representing the most deaths.

Flood fatalities, much like the events which cause them, have a very clear seasonal pattern, with June-July and November-January reporting the most deaths from flooding. When looking at deaths from floods, storms and other weather hazards, the biannual spike is less pronounced, instead we can observe a significant trend towards winter deaths in extreme weather events.

**Figure 4.1-3 Number of fatalities – Seasonality of flood and other extreme weather fatalities:**

Pattern of weather hazard casualties by season during 2000-2014. The winter period December-February has a higher proportion of overall weather hazard casualties, as well as slightly more flood deaths than other seasons.
In terms of aggregate totals, there is no obvious trend in weather deaths over the study period; overall death tolls are neither rising nor falling. While suggestive, the 15-year period is insufficient for a definitive analysis of trends. To verify the scale of fatality reported for the period, it is useful to examine fatalities reported in EM-DAT: the CRED/OFDA International Disaster Database (Guha-Sapir et al., 2009). For the purposes of Figure 4.1-4, EM-DAT was filtered for the UK from 1950 to 2015, for hydrological and meteorological hazards, specifically floods and storms. The results show that EM-DAT has records of four high death toll years in that period (over 20 victims), the death toll for three years (1953, 1990, and 1991) is much higher than anything reported by the project database for 2000-2014. Overall, there are spikes in the first half of the period, but more fatalities are reported after 1980. For the duration of the study period (2000-2014) the database pattern of peaks and troughs in fatalities is consistent with EM-DAT. However, the totals from the study database are higher.

![Figure 4.1-4 Number of fatalities – Fatalities reported in EM-DAT (green line) and the fatalities database (black line) for UK floods and storms](image)

Comparing fatalities for floods and storms reported in EM-DAT and the current fatalities database. Overall, the shape of the fatality graph for the period 2000-2014 follows a similar pattern in both datasets, but the project database adds several cases to those recorded by ED-DAT. EM-DAT reports 15 multi-fatality years for the preceding 50-year period, two of which have death tolls higher than anything reported for the 15-year study period. The first spike is 1952, which represents the 34 casualties of the Lynmouth flash flood in North Devon. 1953, which had some of the greatest death tolls from the North Sea storm surge impact, is not reported here, because a storm surge falls under a different event category in EM-DAT. The 1990 spike represents Burns' Day storm in January 1990, which claimed at least 83 lives. The high point reported for 1991 is likely to be a combination of several events, including a severe winter storm in February and wind storms later in the year. A more precise explanation for the total could not be established.
Annual death tolls reported by the project database are higher than those generated by EM-DAT, but follow a similar pattern of peaks and troughs, which suggests that the database is broadly accurate and additive to existing data. Although the same hazards are reported, the precise numbers do not match; the project database identifies between five and 18 additional fatalities for each year. This is most likely due to the depth of analysis by the project database: the newspaper reports provided more instances of fatality than official figures. The difference can also be attributed to the definition of direct fatality and which types were included, which is documented in detail in Chapter 3.

Additionally, the period has featured few high death toll weather hazards compared to the historical UK weather record. The North Sea surge of 1953 is estimated to have claimed 307 lives in England, 58 of them in a single night on Canvey Island in the Thames estuary. 22 people died during the October storm of 1987, many from falling trees and debris. Besides a sharp spike in 2007, fatalities fluctuate around the median each year. The next chapter maps casualties onto a time series of hydro-meteorological hazard events to investigate the relationship between event magnitude and the level of fatalities. At a glance, we know that there were a number of high magnitude events in 2007, most notably the June-July floods; the summer months explain about a third of that year’s fatalities (17 out of 41). At the same time, while there were several significant flood events in 2012, which caused severe disruption and significant property damage (April, June, August, November), there were relatively few casualties that year. These high level observations suggest levels of complexity which should be considered by models that propose a linear relationship between hazard magnitude parameters, such as water depth and velocity, and the number of fatalities (Boyd, 2005; Jonkman et al., 2008). Similarly to Ruin et al. (2008), we need to investigate the typology (Terti et al., 2015), speed of onset, and spatial coverage of the event in its relationship to fatalities.

4.2 Fatalities by hazard type
As discussed in Chapter 3, the early pilot method showed that fatalities from weather events other than floods could be extracted from Lexis Nexis® with comparative ease and little loss in efficiency. Although these records have been analysed less rigorously than those reporting incidents of flood death, they can provide further insight and put flood fatalities in the context of other weather hazard casualties. Importantly, they also suggest opportunities for further research into weather casualties.
and their demographics. Therefore, we will step away from floods and their casualties for a moment and examine what, if any, patterns emerge when looking at deaths from other weather hazard events. This section looks at the aggregated number of casualties from all categories of weather death investigated – victims of storms, high winds, and blizzards – comparing their scales, circumstances and case studies to those of fatal flood victims.

**Table 4.2-1** breaks down cases of extreme weather fatality by hazard type and year. Overall, 225 individual cases of fatality were identified for the period 2000-2014 based on newspaper reports extracted from Lexis Nexis®. Flood fatalities represented just under a third of these casualties. The rest could be attributed to accidents in high winds, storms (excluding some high wind and wave induced accidents), and snow storms/blizzards.

Chapter 3 provides an in-depth discussion of how hazard types were consistently categorised. For the purposes of this chapter, it is useful to remember that event typology was identified primarily through the language of the article, and then confirmed through adjacent reports and, where ambiguities remained, MetOffice extreme weather case studies (MetOffice, 2018a). Deaths in high water inland, or specific coastal flood fatalities are counted as flood fatalities. Deaths associated with wave impacts, offshore deaths during recreational activities, or deaths on the sea front in severe weather are mostly classified as storm fatalities. Deaths from blunt trauma of trees felled or masonry dislodged by winds, as well as deaths associated with toppled vehicles or objects inland are categorised as gale fatalities. The storm and gale distinction has a few case studies where the causal hazard could be disputed, in particular concerning gale fatalities on the coast. However, overall, the category distinctions are consistent and evidenced in the database.
Table 4.2-1 Total fatalities for the study period 2000-2014 by year and type of hazard:
Overall the distribution of casualties by hazard type shows that the proportions for each weather event are similar by their means, with snow deaths being slightly less frequent. 2007 stands out at the highest death frequency year for floods and storms, and second highest for gales.

<table>
<thead>
<tr>
<th>Year</th>
<th>All Fatalities</th>
<th>Flood</th>
<th>Storm</th>
<th>Gale</th>
<th>Snow/ice</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>13</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>0</td>
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</tr>
<tr>
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<td>12</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>% of total</td>
<td>28%</td>
<td>21%</td>
<td>36%</td>
<td>15%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.2-1. Fatalities by hazard type 2000 – 2014:
There is no clear trend in fatality totals for different hazards. Clearly storm and gale deaths combined represent the greatest death toll. Snow/ice deaths are episodic; they do not occur every year, because significant snow fall events do not occur in every part of the UK annually. Other hazards are represented by at least one death almost each year of the study period.
4.2.1 Deaths from gale impacts

Gale force winds were the most perilous hazard in the study period, with 81 fatalities recorded, although the numbers are largely driven by a handful of major events. Whereas floods in the UK which cause fatalities tend to do this in isolated cases over several incidents during the winter and summer months, high winds kill either several people or none at all. The geographical footprint of a fatal high wind event is larger than that for a flood, with casualties occurring across regions during a high wind weather event.

In this study, a major fatality-inducing weather event here denotes a meteorological event in a month when more than the annual average of fatalities are reported for the specific hazard. The annual mean for wind related deaths is 5.4; using the Met Office’s Climate Summaries\(^2\) it is possible to match the weather conditions with those months in the database which report more than five deaths in high winds.

A severe wind storm, which recorded speeds around 85 mph, at the end of January 2002 brought down power lines and trees in Scotland. At least four casualties can be attributed directly to this event, and a further six incidents of wind casualties in the north of England occurred around the same time.

Storm-force winds at the end of October 2002 reached over 97 mph in Swansea and affected wide regions of the north and west of England; seven wind casualties are reported for this period, most of them occurring on the roads.

January of 2007 was a mild month overall, but incidents of gusts and blustery showers were reported at different points in the latter part of the month. Winds of 77 mph were recorded in southern England, and 100 mph gales affected remote areas of Wales. 14 wind-based casualties were recorded that month all over England and Wales, most from falling branches and blunt injuries with flying debris. This was the highest number of weather hazard deaths recorded in any month for any hazard for the study period; it is interesting to note that although no extreme storms or

\(^2\) Meteorological summaries provided by the UK Met Office help to contextualise news reports of extreme weather, which do not always provide sufficient detail on the magnitude of the event: (‘Climate summaries - Met Office’, 2018)
hurricanes were reported for this period, isolated gusts and gales caused significant damage over a very large area.

Finally, it is worth mentioning St Jude’s storm in October 2013, which does not strictly fall into the parameters described above for a multiple fatality wind event. Four deaths can be attributed to the winds raised by St Jude, which is below the cut off number of casualties. Even then, only two casualties are direct deaths from falling trees, the remaining two victims died in a gas explosion caused by a falling tree in Hounslow, London. However, the storm and its wind force varying from 75 to 99 mph in different locations, is an example of a named, predicted, and forewarned of event, which caused multiple casualties. The influence of warnings and their dissemination will be further interrogated in Chapter 8: The Protective Effect of Warnings; for now, it is interesting to observe, that although the scale of casualty during St Jude is similar to the unspecified and dispersed multi-fatality wind events in 2002 and 2007, the nature of these casualties is different, with victims dying indoors, for instance.

It could be speculated that the results for gale fatalities are incomplete, and an artefact of the database search protocol, as gale deaths were only a secondary focus of the investigation. Some smaller event impacts may have been missed by the initial newspaper search, or were simply unreported due to a journalistic bias towards more severe events. However, as Chapter 8 will show, severe warnings for gales are much less frequent than other weather hazards, and so we can assume that the number and circumstance of reported gale deaths is broadly accurate.

Based on the above descriptions, Table 4.2-2 notes some of the differences between incidents of flood death and high wind fatalities.

<table>
<thead>
<tr>
<th></th>
<th>High wind fatalities</th>
<th>Flood fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual average</td>
<td>5.40</td>
<td>4.13</td>
</tr>
<tr>
<td>Total over 15 years</td>
<td>81</td>
<td>62</td>
</tr>
<tr>
<td>Most reported in one month</td>
<td>14 (January 2007)</td>
<td>7 (June 2007)</td>
</tr>
<tr>
<td>Most frequent cause</td>
<td>Blunt force trauma, falling trees and debris</td>
<td>Drowning (asphyxiation) after falling into swollen watercourses</td>
</tr>
<tr>
<td>Deaths per event</td>
<td>Mostly multiple</td>
<td>Mostly single (two for five events)</td>
</tr>
</tbody>
</table>
The analysis in Table 4.2-2 can suggest that high winds in the UK are a more severe hazard risk than floods, in terms of loss of life; they cause roughly 30% more casualties and significant events kill many people. On the other hand, floods have resulted in casualties almost every year since 2000, (none were recorded in 2006). Overall, the two events, although seasonally and meteorologically linked, have very different fatality profiles and attributes.

**4.2.2 Deaths in storms**

The hazard category “storms” in this study was a derivative of the “floods” and “gales” category. Often a report about a major storm, like those for St Jude in October 2003 for example, listed a death that could be easily attributable to high winds i.e. tree or masonry falling on the victim during the storm. Equally, many of the storms reported also induced flash flood conditions; swollen watercourses, inundated roads and fields, perilous fords and bridges. Fatalities in these circumstances were classified as flood, even though the initial report specified storm conditions.

Hence, storm hazard deaths mostly feature the remaining deaths; firstly, coastal casualties where wave power can be to blame for the fatality. As no coastal flood deaths were identified for the study period, almost all deaths along the coastlines of the UK featured in the database are listed as flood deaths: these include being swept away by waves and drowning in storm conditions at sea. Deaths at sea were only recorded if the victim was engaged in recreational water sports close to the shoreline – fatalities in commercial shipping and professional sailing were excluded. Recorded deaths at sea are mostly kayakers, anglers and recreational boating accidents. Additionally, storm deaths in the database record casualties reported to have died in “atrocious weather conditions”, or similar descriptions, by the newspaper reports. These are usually in reference to deaths of mountaineers or hill walkers where the incident surrounding the death is unclear, but stormy weather is reported. Exclusion criteria for storm deaths include drowning in swollen rivers, which instead is categorised as floods, and blunt trauma from falling objects dislodged by wind. This leaves the list of storm fatalities to include a variety of coastal drownings, blunt trauma from falls or rocks, wave impact and drowning in cars swept by waves.

Still, storms account for 48 casualties in the database, with an annual mean of 3.2. Similar to both floods and gales, there is a significant spike in fatalities in 2007 when 11 people died in storms,
although the seasonal spread in that year is much more even overall: there were storm fatalities in each season and between one and three cases in five months of the year.

There are three years with no storm casualties at all, which is more than the case with flood and gales, both of which reported only one casualty-free year (2006 and 2001 respectively). The range of casualty numbers for storms is like that of floods, with only one spike and the remaining years reporting death numbers close to the mean.

The lower number of recorded deaths from storms can be seen as a methodological feature of the somewhat residual nature of this category, but based on this it also reports fewer deaths because it is geographically limited – most deaths are recorded in coastal or remote mountainous locations. The smaller range of the fatality count suggests that storm deaths are closer in nature to flood deaths, than high wind casualties, wherein the event is more clearly identifiable and therefore forewarned, perhaps even a preventable risk.

Further sections, which consider the nature of the casualty’s activity at the time of death, will provide more parallels between storm and flood deaths, considering the majority of recreational and sport fatalities reported in this category.

4.2.3 Dying in snow conditions

There is a large and important literature on cold weather hazards, fuel poverty and temperature associated injury, illness, and death; this study does not presume to add to that area of knowledge (Liddell and Morris, 2010; Kelman et al., 2016; Haines et al., 2006). Fatalities categorised as “snow/ice” in the database recognise deaths which occurred as a direct result of encountering extreme snow or ice conditions outdoors. These include: hypothermia in blizzard conditions or sudden snow storms; falling and blunt trauma from slipping on ice in poor weather conditions, including low visibility, excluding vehicles skidding; hypothermia and asphyxiation after encountering an avalanche; drowning and asphyxiation after falling through ice into extremely cold bodies of water. All of the snow fatalities in the database report victims who died outdoors, whereas the wider cold weather hazard vulnerability literature mostly reports on home deaths due to insufficient heating (Sartini et al., 2018).
Arguably, many deaths reported under this category may not be attributable to extreme or sudden weather events, which describe the other fatality categories. However, the UK experiences an average of 23.7 days of sleet and snow per year (Office, 2018c), which represents less than 7% of all UK weather, making these conditions relatively extreme in a UK context, and their resulting fatalities a reasonable unit of inquiry for this study.

Clearly, seasonality plays a crucial role in the pattern of reported deaths from snow and ice. Of the 34 fatal incidents identified in the database, 25 or almost three quarters happened between the start of December and the end of January. One incident was reported in November 2006 and one in March 2005, both featured two victims. The rest were extreme winter events, with some mountain incidents reporting temperatures of -20°C – very extreme conditions for the UK.

This category reported the most null years: eight years with no deaths in snow and ice conditions. These coincide with milder winters experienced by the UK. 2009 and 2010 report the most snow fatalities (16 and eight respectively), in all winter months from a variety of locations. This is in line with the mean winter temperature reports for the study period, when 2008 and 2009 were the coldest years (MetOffice, 2018b). 11 out of these 24 deaths occurred in the mountains, mostly in Scotland, but also on Snowden. The reasons and decisions of victims to pursue outdoor activities in perilous conditions and remote locations, like mountains, are explored in more detail in Chapter 7, but we can definitely observe a geographical (north) and population density (remoteness) parameter to many of the deaths in snow. Similarly to the coastal storm deaths, many of the deaths in this category are geographically limited by the conditions which cause them, and the activities which precede them. The rest of the snow and ice deaths in these two cold winters are scattered around English counties, and mostly represent accidents in frozen bodies of water and hypothermia from sudden onsets snow storms.

It is interesting that there were no snow and ice deaths reported by the database between 2010 and 2014. Although the winters during these years had mean temperatures above 0°C, they were not the warmest winters of the study period. Exploring why snow and ice deaths were avoided in the latter part of the study period is probably beyond the scope of this analysis, but the observation itself is noteworthy.
Figure 4.2-2 Fatalities from extreme weather events in the UK 2000 – 2014 split by hazard: 2007 reported the highest number of deaths for both floods and storms, wind deaths that year were the second highest for the period, snow deaths were low but present. Flood and storm deaths occur almost every year; deaths from high winds do not happen every year, and snow deaths are even rarer.

Overall, floods and their resultant deaths seem to have a frequency and magnitude pattern which is unique in the context of deaths caused by other weather hazards. There is a steady annual pace of flood fatalities, but the range of the number of deaths reported is narrow and close to the mean 4.13 per year. Storms have a similar range and pattern of fatality, but they do not cause deaths every year. Wind fatalities are a very different phenomenon, and although we might be able to compare the incidents of snow deaths to that of floods (remote, recreational), they are too seasonally clustered and do not occur every year.

Therefore, it makes sense to explore flood deaths separately, firstly by considering them in the context of other causes of death, which are not linked to weather hazards.
4.3 UK hazard mortality in context
During the year 2012, ten people in the UK drowned in the bath, according to the National Water Safety Forum (WAID, 2013). All of these deaths were categorised as accidents, no suicide attempts were suspected, and the age distribution was skewed towards the elderly. With six flood casualties in the same year, and an annual average of 4.13 deaths from flooding, the context of other accidental and avoidable deaths, in water or other circumstances, becomes an important backdrop to this study.

It is fair to say that extreme weather events are not a major killer in the UK. Only 225 deaths were identified for the period 2000-2014 with an average annual death toll of 15 and a median of just 12 casualties. Flooding accounts for about 28% of those extreme weather casualties.

The Office of National Statistics regularly reports on “avoidable deaths” in England and Wales. Although the focus of these statistics is on disease amenable to treatment with timely and improved healthcare provision, there is also a definition of preventable deaths, which include death from accidental injuries – a category which would include the deaths from extreme weather hazards reported by this study. Accidental deaths are not the main cause of avoidable death in adults in the UK: for the year 2014, the biggest categories were neoplasms and heart disease (Office for National Statistics, 2014). However, accidental injury was the biggest cause of avoidable death amongst children and young people, accounting for 14% (195 cases) of avoidable deaths between 0 and 19 years of age.

Looking at accidental deaths in England and Wales over a longer period, shows that around 17,500 people die annually from preventable accidental injury. Each year the figure has remained close to the mean, although a rising trend can be observed towards the end of the period 2000-2013 (Office for National Statistics, 2015).
Overall, on average over half a million people die annually in the UK: the mean number of deaths per year for the period 2000-2014 is 510,958 (Office for National Statistics, 2015). This means that the number of accidental deaths accounts for around 3.42% of all deaths annually. So, to put the deaths from the database in context, annual weather hazard deaths represent 0.09% of all accidental deaths, and 0.003% of deaths from all causes. The proportion of deaths from flooding is even less, with 0.02% of all accidental deaths and 0.0008% of all UK deaths annually.

This first important finding demonstrates that the level of direct fatality from floods and extreme weather hazards in the UK is very low. These hazards are not a major killer in the UK, and do not cause a number of deaths that could feature on the statistical radar. The mean annual mortality of 15 suggests these to be very low risk to life events, almost insignificant compared to less complex accidents and common illnesses. Therefore, although the context of magnitudes is enlightening, looking at real numbers is not necessarily helpful for further analysis. The next step is to look at trends in mortality from floods and other hazards, to see if it matches the trends for broader categories of death.
Figure 4.3-2 Weather event fatalities compared to death rate trends a) for all deaths, b) for accidental deaths in England and Wales:

Weather event deaths are a very small percentage of total UK deaths. The death rate in the populations has been slowly rising, and the number of accidental injury deaths peaked in 2013. For the same period, deaths from weather events show no clear trend (Office for National Statistics, 2015).

The lack of trend in weather fatalities is further evidenced by the lack of association between them and total and accidental deaths throughout the UK. Whilst both total deaths and accidental deaths in the UK report a slow rate of rise for the study period ($R^2 = 0.8$ and 0.3, respectively), weather hazard deaths are random and show no trend. Total numbers are insignificant in their scale and random in terms of change over time, meaning that the dataset needs to be analysed in its own context, without relating to the wider picture of UK mortality.
In order to draw more certain conclusions about UK extreme weather mortality, we need to consider the number of annual deaths normalised in terms of the size of the population. Expected annual fatalities per million population is a standard health and safety metric, which can allow weather fatalities to be compared to other risks of death. In standard risk assessment practice, a fatality rate less frequent than one person/year per million of population is regarded as too low to act upon. For example, the Health and Safety Executive treats risks in the workplace below the As Low as Reasonably Practicable threshold (ALARP) as “so insignificant that they need not claim attention, and the regulator need not ask employers to seek further improvement provided that they are satisfied that these low levels of risk will be attained in practice” (HSE, 1992, pp.10). This is a risk level that is unlikely to worry people enough to alter their behaviour, provided normal precautions were in place: this is a daily level of risk to life, such as electrocution from domestic appliances; and it is ten times less than the very tangible risk of dying in a car accident (HSE, 1992).

For the UK, the rate of death per year from all weather hazards fluctuated between $0.78 \times 10^{-6}$ and $0.669 \times 10^{-6}$ during the period 2000 – 2014 while the population was steadily rising. The rate for flood death was even lower, and held steady at shows all weather hazard and flood fatalities in terms of annually adjusted deaths per million of population. $0.062 – 0.068 \times 10^{-6}$. Both of these rates are far below the negligible risk threshold described above. Figure 4.3-3 presents the time series for a normalised rate of death from weather and flood hazards in the UK.
Figure 4.3-3 Weather hazard and flood fatalities in the UK per million population between 2000 – 2014:
Deaths rates per million of the population are very low, and below the nominal $10^{-6}$ threshold for negligible risk, especially for flooding. Deaths from weather hazards fluctuate from year to year, with a spike in 2007, while deaths from flooding stay more constant.

The low risk of flood and extreme weather death, demonstrated in Figure 4.3-3, fluctuates for all weather hazards, but stays constant for floods, even considering the spike of 2007. Overall, risk to life from this cause is extremely low, so low in fact that it falls below the threshold of mortality risk the Health and Safety Executive has identified as requiring any reasonably practicable measures to reduce further (HSE, 1992).

4.4 Discussion

The findings presented in this chapter show that deaths from weather hazards in the UK are rare. The lack of large multi fatality weather events also suggests that mortality is random and accidental.

The key finding, and one which needs to preface the rest of the analysis, is the low rate of hazard fatality in the context of the UK death rate. In the period 2000 to 2014 only 0.0029% of all deaths could be attributed to extreme weather events in the UK, the overall rate of mortality is less than one person per year per million of the UK population. Whereas total UK deaths have been slowly
rising during the study period, in part linked to the growing population, the weather event deaths show no significant trend or change over time.

Table 4.4-1 Total, accidental, and weather deaths, with annual change, 2001 — 2013:
All three fatality categories rise and fall in different years and in different proportions. This suggests that whilst accidental deaths are not linked to the overall death rate trend, weather hazard deaths are even more random through the dataset, with no emerging trend.

<table>
<thead>
<tr>
<th>Year</th>
<th>Deaths in population</th>
<th>Change</th>
<th>Accidental deaths</th>
<th>Change</th>
<th>Weather hazard deaths</th>
<th>Change</th>
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<td>-5</td>
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<td>2013</td>
<td>532,498</td>
<td>-2,858</td>
<td>18,765</td>
<td>1,481</td>
<td>5</td>
<td>-22</td>
</tr>
</tbody>
</table>

There were 225 deaths found during the period 2000-2014 that could be directly attributed to the impact of an extreme weather hazard: 62 of these were specifically attributable to floods. This low figure, in the context of several high risk weather events annually, is a testament to the strengths of natural hazard risk management in the UK, the preparedness of the population, and the effectiveness of warnings and first responders. It also suggests that there is an inverse association between fatality impact and event severity, in that the types of weather hazards affecting the UK are less severe in global terms and pose a greater risk to property than to life. This will be explored in more detail in Chapter 5.

The magnitude and severity of the event is an important contextual parameter for analysing UK floods and their impacts. From flood fatality literature (Handmer et al., 2001), we know that flash flooding kills more people than slow onset floods, although more non-fatal injuries and indirect health impacts are associated with the latter. With several working definitions of flash flooding applied in the literature, it is hard to identify which UK events can be directly classified as flash flooding. However, considering impacts on a case study basis, we can name the Lynmouth flood in
North Devon in 1952 as a flash flood case study, which claimed 34 lives. Characterised by a rapid speed of onset, high velocity of the flowing flood water, a narrow channel which led to significant depths of flood water, this flood had all the attributes of a flash flood event (Cave et al., 2009). Looking at a list of flood events identified for the period 2000-2014 in the UK (‘Climate summaries - Met Office’, 2018), few can be classified along the same parameters of speed, depth and velocity. The River Ouse floods October-November 2000 reported flood water depths of several feet, the August 2004 flood in Boscastle, Cornwall was exacerbated by the narrow valley terrain, increasing the velocity of the water and causing building collapse. The summer 2012 floods, with their worst impacts in Newcastle and Tyneside, saw months’ worth of rainfall in the space of a few days, which caused waters to rise rapidly in urban and suburban areas (Archer and Fowler, 2018). Although all of these events would fall under the category of the severe flash flooding, they did not actually lead to any direct deaths. The reasons for the avoidance of fatality will be discussed in Chapter 7, which will focus on behaviours and choices keeping people safe, and Chapter 8, which will look at the protective effect of warnings. In contrast, the only event in the study period to have several fatal impacts was the Tewkesbury flood of July 2007, and this was a relatively well forecast and gradually developing event, with the several flooded rivers bursting their banks sequentially. The 2009 floods in Cumbria, as well as a number of coastal events in Dorset and Wales, did claim lives, mostly singular, on five occasions in pairs. However, what can be clearly observed in the database is the absence of a major Lynmouth scale flash flood in the study period, which caused fatalities.

This is very different from the situation in continental Europe and North America, where flash flooding as well as severe riverine flooding causes building collapse, inundation and multiple fatalities at a greater frequency. In France, the Gard region floods of 2002 killed 23 people, and the Var flash floods in 2010 caused 25 fatalities. A further 25 died during the October flash flooding on 2000 in northern Italy, and at least 30 people were killed by flash flooding and resultant mudslides in Sicily in October 2010. In the United States, 18 people died in a flash flood in Los Angeles in 2003, floods which swept several midwestern states in January 2007 left a death toll of 24, and a further 20 people died in the summer of 2010 in Arkansas and Oklahoma from riverine flooding. This is far from an exhaustive list of multi fatality flood events in developed countries with well-established disaster management response systems, taken from EN-DAT for the period 2000-2014 (Guha-Sapir et al., 2009).
EM-DAT also allows comparison of some values of the footprint of the flood event, although not all disasters have these data. A brief comparison between these shows that the summer 2007 floods in the west of England – the only multi-fatality event in the UK for the study period – is reported at almost 25 thousand square kilometres, although this clearly covers multiple catchments outside of Gloucestershire, where the fatalities occurred, including Hull, Sheffield, and two incidents in Wales. The fatal floods in France and Italy mentioned above range in footprint, where data is available, from 1000 to 10,000 km², which supports the research that suggests that smaller footprint events in smaller catchments are more dangerous (Ruin et al., 2008).

But where smaller catchments have experienced more rapid flooding with a shorter lag period after a rainfall event, such as Cockermouth, Workington and the river Derwent in Cumbria in November 2009, only one death was recorded – that of the police officer preventing cars from crossing a bridge over the swollen river. However, here we also need to consider the validity of scale comparisons as reported in EM-DAT; whilst we know from Met Office summaries (Office, 2018a) that the fatal flash flooding was focused in Workington and the Derwent, EM-DAT reports its footprint to be more than 100,000 km².

Therefore, whilst it is difficult to get data for a direct international comparison, we can use case studies to claim that for the study period 2000-2014 there have been no multi fatality flood events in the UK, and no significant fatal floods have occurred since 1952 (Lynmouth) and 1953 (Canvey Island). However, significant floods, including flash floods, have occurred causing significant damage, but no deaths. At the same time, multi fatality floods have struck other countries with similar levels of protection to the UK on several occasions during the study period and since. The impact and magnitude of these flood was often greater, although no direct comparison can be made with available data. However, the scale of fatality tells a stark and different story to the relative safety of the UK.

The rate of flood death per year per million population is less than 0.07. This is far below the $1 \times 10^{-6}$ threshold that is used to identify tolerable risks, which are close to daily risks to life, have little impact on a person’s level of alarm or behaviour, and below which it is not reasonable to consider specific preventative action (HSE, 1992). The rate of fatality from all-weather hazards is slightly higher and above 0.1 per million population for most years of the period 2000-2014, but still almost
ten times less than the risk level considered to be reduced so far as is reasonably practicable (SFAIRP). For example, in the Netherlands, the Ministry of Housing, Spatial Planning and Environment also sets a threshold for individual risk IR < $10^{-6}$ per year below which risks should still be reduced as low as reasonably achievable (ALARA) (Jonkman et al., 2003), but below which risk is a background noise and there is no legal obligation to reduce the risk to third parties further. The findings on total weather fatality numbers and deaths therefore suggest, that in the UK they have reached a level of risk which is too infinitesimally small to justify much further government effort at risk reduction. The cost of any investments to prevent loss of life from extreme weather are likely to be disproportionate and might be better spent on addressing other causes of preventable death, like road traffic accidents, where the mortality rate is higher and the return on preventive investment, in terms of lives saved, is likely to be greater.

To further contextualise this finding, it is instructive to compare the rate of fatality from weather hazards in the UK to that of the United States. Despite the vast difference in weather severity, the highly developed disaster risk reduction systems in the two countries may suggest that mortality risk should be similar. As Figure 4.4-1 shows, this is the case most of the time.

![Figure 4.4-1 Weather hazard fatalities, UK and US per million population 2000 – 2014:](image)

The risk of death from all weather and flood hazards is similar in the UK and US, although slightly higher in the US for most years. The notable spike in US fatalities represents hurricane Katrina in 2005; this year reports 1016 hurricane deaths. The UK has a much smaller spike in 2007, reflecting that year’s summer flood and winter storm events. For flooding, the UK is noticeably safer than the US. US weather hazard fatality deaths are taken from the National Oceanic and Atmospheric Administration (NOAA) data (NWS, 2017), reflecting deaths from floods, hurricanes, winter storms, and wind events. US population data from the 2000 and 2010 US Census estimates (Bureau, 2017).
In both the US and the UK risk of death from flooding is infinitesimal. Unlike the risk of death from all hazards, there is very little fluctuation in flood deaths risk during the period. The magnitude of risk for all weather hazards in the UK is similar to that of the US, apart from the catastrophic impact of hurricane Katrina. This suggests that for the majority of events, both countries achieve levels of protection that are reducing risk to life so far as is reasonably practicable and below the generally established levels of acceptable individual risk (IR < 10\(^{-6}\)).

However, even if the risks are already as low as reasonable practicable, they are not completely negligible. As we have seen, deaths still occur in floods and other weather hazards, triggering media attention, emotional distress, and policy response.

In the UK, disaster risk reduction policy and practice has placed significant value on human life. The protection of lives and livelihoods is specified in the key documents identifying the priorities of disaster risk protection (Defra and Environment Agency, 2011). Both the Environment Agency and the Natural Hazard Partnership have commissioned research into fatal flood impacts, their factors, and prevention mechanisms (Wicks, 2013; Cave et al., 2008; Environment Agency and DEFRA, 2008). Although there was no comprehensive investigation into the scale of flood and extreme weather fatality in the UK before the present study, policy and decision making has been targeted towards this issue. It may be that the findings of the database have been low due to this policy focus driving down fatalities, leaving only random and accidental deaths to be counted. Whether this low number is in fact a factor of protection and warning, or whether it can be linked to weather patterns and geographical factors will be described in the following analytical chapters.

The news often reports flood and other weather hazard deaths in detail because they are both unusual and dramatic, which gives the news value (Escobar and Demeritt, 2014). This is especially true in the context of the relative safety of people in the UK from hazard; in terms of disaster risk reduction theory and practice, the lives of people in the UK are relatively well protected from extreme hazards. But death is only one potential flood impact, the main focus of prevention and policy remains the protection of property and utilities: this is built into the UK’s flood warning and extreme weather warning system, which specifies whether risks are relevant to life, property, or
services (Chapter 8). The winter 2013-14 floods in England and Wales saw no casualties but caused over £320 million in property damage, affecting over 10,000 homes (Chatterton et al., 2016). In the scale of impact and the accidental nature of many flood deaths, it could be argued that lives are sufficiently, potentially over, protected, whilst properties remain increasingly at risk.

### 4.5 Conclusion: low numbers = low risk?
This first angle of analysis attempted to comprehend total aggregated numbers of fatalities from flooding and extreme weather events in the UK between 2000 and 2014 to address the gap in data which could inform policy of flood casualties. The relevant research question for this chapter was:

- Who is dying from flooding and other weather hazards in the UK?

By analysing aggregate numbers of flood and weather hazard casualties, the chapter tested the hypothesis that flood and other weather hazards in the UK lead to very low numbers of casualties, which do not follow any temporal patterns or historic trends.

The main finding, which supports the hypothesis, is that the numbers are low: insignificant in terms of national mortality rates, including those for accidental deaths. Although it is beyond the scope of the immediate study, it could appear these numbers have been low since the major catastrophic floods of the 1950s. No clear temporal or historic trends have been found, besides vague seasonal trends which are not significant in the current sample size.

One important question for analysis, which arises from the findings of this chapter, is whether patterns of fatality exist at all, or whether their random nature renders them unsuitable for systematic analysis. The following chapters will examine the dataset of fatalities from a range of angles to search for meteorological, geographical, and behavioural patterns.

Another important question is about the explanation for the relatively low level of mortal risk from flooding and extreme weather. Compared to other developed countries, with established disaster protection systems, very few people die in the UK from weather hazards. However, whether this is a function of existing levels of protection, or whether the existing protection is a superfluous response to a low death rate, is a difficult question to answer with the available data. Additionally,
the low rates may be a result of an overall milder weather pattern in the UK with fewer extreme events overall.

For the first time, this study has comprehensively documented all flood and extreme weather hazard induced fatalities in the UK for the period 2000-2014. Proceeding to the following stages of analysis, we know that the aggregate number of fatalities is low and their occurrence is seemingly random in terms of seasonal and annual trends.

However, aggregate numbers do not tell the whole story, especially given the lack of trends. Each death is singular data point, dependent on unique hazard circumstances, with a meteorological, geographical, socio-economic, and behavioural dimension. The following set of analytical chapters will deal with each of these in turn. Turning to the work of Ruin et al. (2008), we first investigate the physical nature of the hazard, by looking at the potential intensity of rainfall which preceded each flood casualty.
Chapter 5 Fatalities and Their Floods

We keep on coming back to the impacts of the Great North Sea Floods of January 1953, and the 58 lives that were lost in a single night on Canvey island in the Thames Estuary, as well as others up and down the East coast. This was a dramatic and rare natural disaster for the UK, one that remains fresh in the collective memory, with regular commemorative events and reports to mark the anniversaries of the disaster. It was the hydro and meteorological causes of the flood, met with an inadequate defence infrastructure that made the storm as destructive as it was. The flood was a result of a storm surge during a moment of high tide, which together generated sea levels unprecedented in recorded memory. These high water levels could not be withstood by the tired and underkept pre-war sea defences (Vinet et al., 2012). As a result, massive inundation occurred during the night, when many residents were unaware of the weather. Extrapolating from the case of Canvey Island, the question of association between specific impacts and flood type becomes worthy of further analysis. Are certain types of UK floods more likely to lead to fatalities?

The previous chapter has shown that flood fatality rates in the UK are noisy and unpredictable, with few events claiming more than one life and many floods passing without casualties. Canvey Island was the last significant multi fatality flood event, and the nature of the storm surge was a clear reason of its tragic potency. Significant storm surges have come and gone since then, sometimes claiming the lives of people on the shore.

Within the fatalities database, there are no deaths recorded from high tides and tidal flooding. This is an important observation in terms of risk reduction strategy: the global rising sea levels could suggest the growing risk of tidal surges. Mean sea level rise around the UK has been calculated to rise by 1.4 mm ± 0.2 mm/year during the twentieth century (Woodworth et al., 2009) with even greater rates of rise have been estimated at 2.43 ± 0.09 mm/year for Sheerness in the Thames Estuary (Haigh et al., 2011); this coastline bore the most destructive impacts of the 1953 sea surge, which has since been used as the benchmark high sea levels. However, it appears that since the improvements in coastal flood protection, there have been no major fatal tidal surges, and no one died from this type of hazard during the study period. If there have been tidal surge fatalities, these would be classified either in the storm or flood category, depending on the location and circumstances of the fatality.
Looking specifically for significant storm surges during the study period, low pressure generated rises in sea level of high severity (level 3-5), only two events from the study period are identified by the crowd sourced list on surgewatch.com – 9th November 2007 and 5th December 2013. The first date has no associated fatalities listed and in fact no weather deaths were reported during that month. The December 2013 storm surge event was well forecast and preceded with large scale evacuations. In fact, the 2013 storm surge surpassed the wave height and onshore levels of the 1953 disaster (Spencer et al., 2015). Yet still there were no coastal casualties. In the database, this date is associated with a gale impact death (Victim ID 13.12.06), crushed by a storm felled tree in Nottingham, and a wind caused road collision fatality, which is not within the scope of the database. In other words, this specific event type is not found to correlate with fatalities after the 1953 example.

Scanning the database for tidal flood fatalities, and specifically tidal inundation, again shows no recorded deaths from this direct cause, despite the significant toll of the 1953 inundation. It can be speculated that this is a consequence of significant improvements in coastal protection since, and in many cases as a response to, the 1953 Canvey Island disaster. Morphologically speaking, storm surges and tidal floods, so graphically captured in George Eliot’s “The Mill on the Floss” which opened this analysis, have ceased to be a risk to life in the UK.

Storm waves, however, generated at high tide by stormy conditions, run through the database as a stark thread of warning to people enjoying coastal recreation. Classified as storm deaths in the database, 26 victims were “swept away”, “dragged out to sea”, “overpowered by waves”, or “swept off the pier”. This includes several multiple casualty events, which involve co-located friend and family groups, many trying to rescue one another and drowning in the attempt. The most serious was the death of five members of a family in South Uist in 2005, who drowned in their cars whilst trying to reach safety, evacuating their remote home. High waves swept their vehicles off the coastal lane, drowning three adults and two children.

Overall, it can be concluded from the similarity and number of case studies that the specific hazard type which includes high waves breaking on the shore in stormy conditions poses a risk to life for people on the shore. The vulnerability of these victims is characterised by their choice of activity and risk taking behaviour, which leads to their own increased exposure: this includes photography, sailing, walking and even “wave-dodging” in dangerous weather conditions. Whilst sea wall
protection reduced the exposure to stormy seas of sleeping coastal populations, like the victims of Canvey island, this type of vulnerability reduction cannot protect all risk taking victims from wave hazards (arguably, a sea wall shielding the South Uist lane could have protected the victims).

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Victim ID</th>
<th>Cause of death</th>
<th>Activity at the time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Jan</td>
<td>14.01.01</td>
<td>dragged out to sea by huge wave</td>
<td>paddling with friends during storm</td>
<td>Loe Bar, Cornwall</td>
</tr>
<tr>
<td>2007</td>
<td>Mar</td>
<td>07.03.02</td>
<td>swept off pier by wave</td>
<td>walking</td>
<td>Mullion Cove, Cornwall</td>
</tr>
<tr>
<td>2007</td>
<td>Mar</td>
<td>07.03.03</td>
<td>swept off pier by wave</td>
<td>walking</td>
<td>Mullion Cove, Cornwall</td>
</tr>
<tr>
<td>2007</td>
<td>Aug</td>
<td>07.08.04</td>
<td>drowned when assault boat capsized in poor weather conditions</td>
<td>sailing</td>
<td>Loch Carnan, South Uist</td>
</tr>
<tr>
<td>2007</td>
<td>Aug</td>
<td>07.08.05</td>
<td>washed off by waves whilst trying to watch the waves, edging close to the shore in stormy conditions</td>
<td>walking</td>
<td>Lochinver, west Sutherland</td>
</tr>
<tr>
<td>2007</td>
<td>Aug</td>
<td>07.08.06</td>
<td>drowned trying to save his sister, who was washed off by waves whilst trying to watch the waves, edging close to the shore in stormy conditions</td>
<td>walking, rescuing</td>
<td>Lochinver, west Sutherland</td>
</tr>
<tr>
<td>2007</td>
<td>Nov</td>
<td>07.11.01</td>
<td>boat capsized in very high wind and waves. Warning attempts had been made by coast guard</td>
<td>sailing</td>
<td>Whitby, Yorkshire</td>
</tr>
<tr>
<td>2007</td>
<td>Nov</td>
<td>07.11.02</td>
<td></td>
<td>sailing</td>
<td>Whitby, Yorkshire</td>
</tr>
<tr>
<td>2007</td>
<td>Nov</td>
<td>07.11.03</td>
<td></td>
<td>sailing</td>
<td>Whitby, Yorkshire</td>
</tr>
<tr>
<td>2007</td>
<td>Dec</td>
<td>07.12.03</td>
<td>Drowned after being dragged out to sea by huge waves, saving partner</td>
<td>walking, rescuing</td>
<td>Blackpool</td>
</tr>
<tr>
<td>2007</td>
<td>Dec</td>
<td>07.12.04</td>
<td>Drowned after being dragged out to sea by huge waves</td>
<td>walking</td>
<td>Blackpool</td>
</tr>
<tr>
<td>2006</td>
<td>Apr</td>
<td>06.04.01</td>
<td>drowned after being swept to sea by 30ft high spring tidal wave on a stormy night</td>
<td>sitting by the sea</td>
<td>Blackpool</td>
</tr>
<tr>
<td>2006</td>
<td>May</td>
<td>06.05.01</td>
<td>swept out to sea by waves in gale-force winds</td>
<td>taking photos on promenade, jumped over a barrier</td>
<td>Blackpool</td>
</tr>
<tr>
<td>2006</td>
<td>May</td>
<td>06.05.02</td>
<td></td>
<td></td>
<td>Blackpool</td>
</tr>
<tr>
<td>2006</td>
<td>Dec</td>
<td>06.12.02</td>
<td>drowned after being swept out to sea by a storm wave, walking near harbour</td>
<td>walking</td>
<td>Ardglass, County Down, NI</td>
</tr>
<tr>
<td>2005</td>
<td>Jan</td>
<td>05.01.01</td>
<td>drowned after storm waves swept away cars on a narrow lane close to the sea. Trying to escape flooded home. Cars were trying to reach safety of family home 200 away when they were swept away.</td>
<td>driving</td>
<td>South Uist, Western Isles</td>
</tr>
<tr>
<td>2005</td>
<td>Jan</td>
<td>05.01.02</td>
<td></td>
<td>driving (passenger)</td>
<td>South Uist, Western Isles</td>
</tr>
</tbody>
</table>

Table 4.5.1-0 Wave victims captured by the fatalities database:
Most were engaged in recreational activities, some actively put themselves at risk e.g. "wave dodging". Notable tragic exception is the Muir family swept off the road during an evacuation attempt in South Uist, Scotland in 2005.
The example of wave hazards seems to be an open and shut case in the attempt to connect hazard morphology and fatalities. The same cannot be said for floods. The flood death case studies in the database describe various impacts of flood events but in no sufficient detail to classify flood types. However, it might be natural to assume that more rapid onset and greater intensity of flooding would more likely lead to deaths, similar to the way in which high and intense wave impact is associated with a greater number of deaths. Newspaper reports of fatalities alone cannot fully examine this hypothesis.

The landmark study by Isabelle Ruin and colleagues (Ruin et al., 2008) suggests precisely this; that the footprint and intensity of floods determines their fatal impact. In Ruin’s study, the smallest catchments (around 10 km²) with rapid response times claimed the most lives (11) in the Gard region floods of 2002 in France. The study focused on a cluster of events, rather than a period study, and a single region where the multi fatality floods occurred. This type of analysis cannot be replicated for the UK beyond examining the Canvey Island disaster, because there have been no multi fatality regional events since 1953; even co-located multiple fatalities do not represent the same unit of risk as the multiple victims in Gard.

However, we can make some morphological assumptions about flood types and their impacts, suggesting that intense rainfall over a period of several days is a precursor to localised fluvial
floods, whereas a sudden extreme rainfall event may be attributable to a rapid onset flood. Therefore, it is interesting to explore historical links between rainfall intensity and the occurrence of flood-linked fatalities.

**The aim of this chapter**

Building on the previous chapter which found no patterns in fatality data, this chapter looks to further develop a response to the first research question:

- Who is dying from flooding in the UK?

And addressing it critically to begin to explore the second research question:

- Are these the people we expect?

The analysis in the chapter achieves this by looking at rainfall precursors of flood casualties to suggest that the expected deaths could be found where persistent heavy rainfall is identified in the meteorological time series.

Building on the type of analysis developed by Ruin and colleagues (2008), several important examples of which can be found in the flood fatality literature, this chapter focuses on the underlying circumstances and aspects of the floods which caused casualties, as well as extreme events which were comparatively “safe”, i.e. did not lead to fatalities.

The analysis does this by testing four short hypotheses: (1) **all flood fatalities occur during periods of rainfall**; (2) **all fatalities are associated with rainfall that can be categorised as extreme for the region**; (3) **that there is a linear relationship between rainfall intensity and chance of flood fatality**; and, (4) that despite this **most rainfall events are not associated with any casualties at all**.

By analysing how far rainfall can predict the occurrence of a flood death in the dataset, we can draw conclusions about the victims being those we expect, i.e. those encountering extreme weather.

Looking at the intersection of high regional rainfall and incidence of death, we find that the cases are random, and whilst this sort of rainfall is a precursor of floods, it is not a precursor of flood death.
5.1 Methodology

5.1.1 Pilot study – major floods and fatalities

Initially, a pilot study was developed, to examine the potential interest from this sort of investigation. The hypothesis was that the intersection between recorded extreme rainfall events and documented floods is random and presents many more “safe” flood events than fatal ones. The methodology was to classify a list of events into those where extreme rainfall coincided with a fatality, and those where extreme rainfall had no associated fatality, based on whether their date matched a report of a casualty in a similar region.

Relying on the Met Office list of past interesting weather events, a time series of flood events judged to be significant, or “interesting”, by the Met Office website was compiled. This list cannot be taken to be comprehensive, as there is no specific methodology for selecting floods for summary besides their assumed public interest. This means that there are likely to be many more flood events which could be of relevance to the database records.

Within the pilot study, 69 flood events were extracted from the Met Office summaries for the study period 2000-2014. In an attempt to manually match the 63 recorded flood death cases to these events, 31 cases of fatality coincided with one of the flood summaries by date i.e. there was a casualty at the same time as the flood. Of these 31 matches, 21 matched the report both by date and region, which suggests that if the 21 deaths can be explained by the reported flood, the remaining ten are probably a consequence of smaller events, not reported by the summaries. And that 42 recorded flood deaths were not a consequence of any of these extreme events.

Table 5.1-1 Pilot study results: Matching Met Office past flood summaries with incidents of death recorded in the database. Floods judged to be significant by this method explain only about a third of the reported casualties.

<table>
<thead>
<tr>
<th>Number of flood events recorded</th>
<th>69</th>
<th>Met office reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of flood deaths recorded</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Coinciding date</td>
<td>31</td>
<td>49% of deaths</td>
</tr>
<tr>
<td>Coinciding date and region</td>
<td>21</td>
<td>33% of deaths</td>
</tr>
<tr>
<td>“Innocent” floods</td>
<td>48</td>
<td>70% of floods</td>
</tr>
<tr>
<td>“Random” deaths</td>
<td>42</td>
<td>67% of deaths</td>
</tr>
</tbody>
</table>

3 List of significant past weather events developed from Met Office summaries (Office, 2018a)
The summaries list many infamous events including the Somerset Levels flooding in early 2014, as well as Dorset and Devon coastal floods in the same period, floods in Newcastle and Tyneside in the summer of 2012, the South East Christmas floods in 2013, Cumbria in January 2005 and other major events in the collective memory, events of significant magnitude and extensive footprint, none of which led to direct flood casualties.

Looking at the remaining “unexplained” fatalities suggests that most of the deaths from flooding were caused by more localised floods and the less predictable swelling of minor watercourses. This seems to match some of the conclusions reached by Ruin et al. (2008), that flood deaths were associated with smaller intense floods and warrants further investigation.

In the absence of a comprehensive database of small scale localised flooding for the UK, this sort of investigation must rely on available hydro and meteorological observation records. With most of the fatality reports referring to severe weather conditions, high river levels, and heavy rain, it is sensible to pursue the analysis by examining precursors of intense localised flooding, specifically intense rainfall. Rainfall is measured more consistently than peak flow, which is not available for many ungauged catchments. This chapter records an attempted analysis of matching rainfall data and incidents of flood fatalities.

**5.1.2 Rainfall data selection and analysis**

For the purpose of this analysis, only the flood casualty incidents were used; a clear and simple methodology was needed to test the hypothesis that flood deaths in the UK are random in relation to the associated flood events and the rainfall events which cause them, and that there are many more “safe” floods and periods of rainfall than fatal ones. In order to simplify the analysis, one casualty type (flood casualty) and one precursor (rainfall) were co-examined: deaths from other weather hazards were out of scope for this analysis. Given that most UK rivers are relatively short compared to major continental ones, lag times in the UK are usually shorter, making extreme and accumulated rainfall a reasonable proxy for potential flooding. A time series for UK surface water flooding is not available at a national scale, but rainfall data, river flow data and ground saturation assumptions can together build up to a close proxy. However, as the pilot study indicated that low numbers of deaths can be explained by major floods, a temporal and geographic coincidence of
heavy rainfall and fatal impact can be used as a coarse proxy. That is to say, a heavy rainfall event can be reasonably assumed to correlate with localised flood impact, and rivers in regions and at times of high recorded rainfall are swollen and high with a reasonable degree of probability.

With a small number of cases under investigation (62), a coarse regional resolution was judged to be suitable for analysis. The location information available from newspaper records is poor quality. It is conceivable that more precise weather conditions could be reconstructed individually for each incident, but the accuracy would be low and the value of such detail is unclear.

Although rainfall data for the UK exists in a number of forms, it took some time to select the most suitable dataset for this analysis. Radar data outputs for the rainfall daily product were considered as a source, but was found to be too detailed and high resolution for locating 62 death incidents over a 15 year period. Tipping rain gauge and river gauge output was also acquired and reviewed. This involved three competing datasets (Environment Agency gauges, SEPA gauges, and MIDAS from CEDA), which provide full national coverage only in combination. Additionally, all three sets are not available for the entire study period, the output is in different formats and difficult to zone. After an attempt to build a time series, this dataset was also rejected. The space and time parameters if each recorded death are uncertain, therefore the meteorological data against which to analyse them needed to have a broad spatio-temporal resolution itself, so that the analysis could match like for like.

Eventually, regional daily rainfall data from the Met Office Hadley Centre Observations Dataset (HadUKP) was selected as the most suitable data source. The HadUKP (Alexander and Jones, 2001) is a series of long-running datasets for precipitation in the UK, which is adjusted and averaged regionally, based on readings from 119 representative weather stations in England, Wales, and Scotland (see Figure 5.1-1). It also has a dataset for Scotland, which was applicable to the analysis, and Northern Ireland, which was not used as no deaths from flooding were reported in Northern Ireland during the study period. The dataset is regularly quality controlled and readily available to download. The dataset presents a coarse geographical resolution, which could safely catch all of the fatality data points, without double counting or missing marginal points, where the actual location of the death was uncertain. As a result of all these features, this dataset was chosen because of its consistency, reliability, national extent, regional scale, availability, and clarity of format.
Chapter 5  Fatalities and Their Floods

Figure 5.1-1 HadUKP region reference map and network of rainfall monitoring stations:
HadUKP divides the UK into four countries and nine regions. The study matched the flood fatalities to the five England and Wales regions, and considered Scotland as one region, creating a total of six time series. Northern Ireland was excluded as no flood deaths were reported there during the study period. Had UKP data is based on observations from 119 rainfall monitoring stations with between 15 and 20 stations reporting on each region. Maps reproduced from ‘Met Office Hadley Centre HadUKP Charts’ (2018) and NCIC Climate Memorandum 29 (Legg, 2011).

Long-running precipitation datasets for English regions, Wales, and Scotland were downloaded as .txt files and converted into Excel tables. Northern Ireland was excluded from the analysis as no flood casualties were reported there during the study period. Although HadUKP splits Scotland into regions, the data is already agglomerated for download. The data was transposed and filtered for dates within the study period 2000-2014. This created six datasets for regional daily rainfall totals for 15 years – South East, South West, North West and Wales, North East, Central England, and Scotland. A time series was created for each region, showing average total daily rainfall for the study period.

After initial data cleaning, graphs were generated, and additional upper quartile and 95th percentile values calculated per region to filter out the most intense rainfall days. Eventually, these were presented as trendlines on the graphs to visually indicate extremes.

Following this, the fatality dataset was added to the time series as a second set of plots. Fatalities were classified by their corresponding HadUKP region and plotted on the same graph as separate markers. This involved adding a previously lacking category of information to the fatalities database.
For other analyses the fatality reports were classified by month and year. It was sometimes difficult to judge precise dates of death from the reports, as all were written after the event and many reference articles were summary ones, giving an overall review of a particular event. Furthermore, not all victims died on the day of the hazard, in a few cases they died later after treatment in hospital. As such, dating the deaths was difficult and imprecise. For the purposes of this investigation, however, the death reports were reviewed once more and it was judged that each death took place within a five day time period prior to the date of the publication. Hence, the deaths were plotted on the time series according to the publication date, and the rainfall time series was adjusted to present a five day running average rainfall total. This allowed for a smoother time series graph and a higher likelihood that death plots could be attributed to peaks in the rainfall data. Any imprecision is visually smoothed by the scale of the full time series – differences in a few days are not visible on a 15 year graph.

5.1.2.1 Space-time scale limitations

It is worth noting that this is a coarse method of analysis with a number of associated limitations. High regional average rainfall may or may not be causal to localised flooding. The regional resolution may overlook highly localised rainfall leading to dangerous flooding (false negative) and also highlight large footprint but low intensity rainfall that is significant at a regional scale but too diffuse and insufficient to cause dangerous flooding locally (false positives). While the former problem of false negatives is likely to be greater in summer, when regional rainfall data misses localised convective rainfall, the latter problem of false positives is likely to be greater in winter, when large scale frontal rainfall is more common. However, despite these limitations, it is probably still safe to say that the absence of rain over a five day average period should be consistent with the absence of sudden flooding and high river levels, which caused many of the deaths. Whereas the presence of heavy or extreme (95\textsuperscript{th} percentile) rainfall and a flood fatality on the same date is likely to indicate a causal link between the intensity of precipitation and the deadly flood. The investigation looked to capture both large and small scale flood events assuming heavy rainfall over several days, or extreme intensity rainfall (95\textsuperscript{th} percentile) was the cause.

A second limitation arises from the uncertainty of locating reported deaths. Allocating fatalities to the HadUKP regions was a process of estimation, especially because many deaths in the East
Midlands were difficult to classify as either Central, West or South East. However, it is likely that the HadUKP outputs also overlap regional boundaries, as regions are designed by the areas covered by the contributing weather stations, which are likely to overlap, if not by catchment, then by territory.

On the whole, the method was robust in using and adapting the given datasets, and presenting clear visualisations of the intersection of hazard precursor and impact. The degree of detail was appropriate given the size of the dataset. A qualitative examination of individual fatality cases and their flood conditions could shed more light on causality circumstances than the present method, but this is the best way to demonstrate the scale of “innocent” incidents of high rainfall, and the random distribution of fatalities across the time series.

5.1.3 Structure of the results

The rainfall data and its intersection with flood fatalities was analysed using a two dimensional contingency table to explain whether extreme rainfall is predictive of death in flooding.

Table 5.1-2 Analysis matrix for rainfall and fatality data:
Double ticks represent predictive events, where extreme rainfall (highest 5% of regional intensity rainfall events) and flood fatalities coincide. Double crosses represent events where extreme rainfall did not lead to a fatal flood event.

<table>
<thead>
<tr>
<th>Extreme rain</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>(2) ✔✔</td>
<td>(4) ✔✘</td>
</tr>
<tr>
<td>No</td>
<td>(1) ✘✔</td>
<td>(3) ✘✘</td>
</tr>
</tbody>
</table>

The aim of this analysis chapter is to understand the relative proportions of the four cells of the matrix. First, we will examine the overall timeseries of regional rainfall, and try to make visual associations between rainfall peaks and flood fatalities, to confirm that fatal and extreme events do, in fact, coincide, but not always. In the second section, we will take a closer look at the proportion of rainfall and fatality events, based on a smoothed 5-day average, which is a better description of flood conditions. In the third section, we will focus on the most extreme 5% of events and their
associated casualties. Finally, we will examine the bottom right corner of the matrix, identifying the “innocent” extreme events, which caused no fatalities.

In this way, the analysis answers four questions, each of which relate to a quadrant of the matrix above: (1) Did it rain when fatalities occurred? (2) Was the rainfall extreme when fatalities occurred?; (3) Is there a relationship between rainfall intensity and casualties, or avoided casualties?; and, (4) How much extreme rainfall is not associated with any fatalities?

The final discussion will bring together the results and establish the relative proportions of each quadrant of the matrix.
5.2 Results

5.2.1 Results set 1: Did it rain when fatalities occurred? Visual association.

The first question for analysis is did it rain when fatalities occurred? The hypothesis is that all flood fatalities occur during periods of rainfall. To test this, the following results present a visual association between rainfall patterns and fatalities.

<table>
<thead>
<tr>
<th>Extreme rain</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td>No</td>
<td>X✔</td>
<td>XX</td>
</tr>
</tbody>
</table>

The first set of results in five parts of Error! Reference source not found. presents time series for regional average daily rainfall from HadUKP and depicting reports of flood fatalities as red crosses on the x-axis. The first set of daily time series allows for a high level visual analysis of the distribution of flood fatalities in the context of regional rainfall. While we can visually match some of the crosses with some of the peaks, we can also see that many rainfall peaks have no associated flood fatalities. Visual analysis suggests there may be some correlation between rainfall intensity and flood fatalities in the South East and South West during the winters of 2001, 2012, 2013; in Central England in the summers of 2004 and 2007. North East, North West and Scotland rainfall is very noisy and cannot be visually associated with incidents of flood death.
Error! Reference source not found. (a) Daily rainfall time series for South West England.

Red crosses indicate a flood fatality in the region. In the South West of England, the high intensity of rainfall in late 2000 may be attributed to the fatality around that time, as can the peaks in late 2012 and late 2013. Although the summer of 2007 saw some of the highest impact floods in the South West, the peaks here are high but not the highest
Red crosses indicate a flood fatality in the region. In the South East, only the late December 2013 rainfall peak seems to be closely matched to a fatality. The other extreme rainfall days are not attributable to the fatality dates at this resolution.
Error! Reference source not found. (c) Daily rainfall time series for Central England.

Red crosses indicate a flood fatality in the region. There are fewer deaths reported in the Central England HadUKP region, but the July 2007 incident seems to be correlated with a darker section i.e. a period of intense rainfall, which is supported by what we know of the summer 2007 floods and could explain the missing representation of this in the South West time series by the location of the representative weather stations and their associated catchments.
Error! Reference source not found. d) Daily rainfall time series for North West England and Wales.

Red crosses indicate a flood fatality in the region. The North West and Wales region overall has more high rainfall peaks and more casualties compared to the other maps. On this time series, the peaks which can be visually associated with fatalities, include late 2000, September 2008 and autumn 2012. However, many extreme peaks are not linked to fatality markers, including a very extreme event in October 2005. And most fatalities between 2000 and 2011 seem to fall quite randomly on the rainfall scale.
Only two deaths are recorded for the North East, of which July 2007 again falls in a darker section, like in Error! Reference source not found. c, indicating the extreme weather which caused that summer’s intense and fatal flooding. However, of the several rainfall peaks (over 30mm) for that region, no intense rainfall days seem to be attributable to a death from flooding, based on visual analysis.
The time series for Scotland shows much more intense regular rainfall (darker colours between 0 and 10mm), so it is less clear where the fatality crosses fall on the rainfall graphic. Most of the crosses appear to be located in sections of intense long-term rainfall, suggesting that high levels of precipitation and ground saturation may have caused fatal water levels. However, similarly to the previous two time series, most of the rainfall peaks do not match incidents of fatality.

The results of this first set of time series show some sporadic visual links between incidents of high rainfall and incidents of flood death. In many cases, these are linked to known regional case studies, for example the floods of June-July 2007. For other incidents of death, it is very difficult to read off the intensity of rainfall at this resolution. Similarly, it is difficult to place the deaths on the calendar using the x-axis as a guide. However, we do see very clearly a large proportion of rainfall peaks completely outside the range of any causal period for a fatality, proving that a large proportion of hazardous weather conditions and surface water flood events do not lead to fatalities. It is also evident that the daily resolution of the rainfall is a significant limitation of these presented results.
5.2.2 Results set 2: Was the rainfall extreme when fatalities occurred?

<table>
<thead>
<tr>
<th>Extreme rain</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td>No</td>
<td>✔</td>
<td>XX</td>
</tr>
</tbody>
</table>

The second question for analysis is was the rainfall extreme when fatalities occurred? The hypothesis is that all fatalities occur during periods of extreme rainfall, which falls into the highest 5% of rainfall for each region.

The second set of results attempts to address the shortfalls of the first by using a 5-day moving average figure for daily rainfall on a log 10 scale. The daily rainfall peaks are also presented in a lighter shade for reference. This produces a smoother time series which is clearer for visual interpretation, and also takes into account the imprecise dating of the deaths. The time series also marks the 95th percentile rainfall days (5% or 274 days of the period), rather than the upper quartile, which segregates a stronger set of evidence of extreme periods of rain. Each figure is accompanied by a table of fatality dates (≥ 5 days) for easier reference.
Chapter 5  
Fatalities and Their Floods

**Table 5.2-1** South West flood fatality publication dates and 5-day average rainfall on the date of publication (Bold indicates 95th percentile rainfall ≥8.63mm)

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09-Dec-00</td>
<td>11.508</td>
</tr>
<tr>
<td>10-Dec-00</td>
<td>11.372</td>
</tr>
<tr>
<td>05-Mar-07</td>
<td>10.854</td>
</tr>
<tr>
<td>27-Jun-07</td>
<td>6.836</td>
</tr>
<tr>
<td>28-Jun-07</td>
<td>7.62</td>
</tr>
<tr>
<td>29-Jun-07</td>
<td>5.004</td>
</tr>
<tr>
<td>14-Aug-08</td>
<td>6.956</td>
</tr>
<tr>
<td>08-Sep-08</td>
<td>9.204</td>
</tr>
<tr>
<td>15-Dec-08</td>
<td>5.956</td>
</tr>
<tr>
<td>23-Nov-09</td>
<td>9.646</td>
</tr>
<tr>
<td>30-Nov-09</td>
<td>8.478</td>
</tr>
<tr>
<td>28-Nov-12</td>
<td>10.456</td>
</tr>
<tr>
<td>26-Mar-13</td>
<td>1.754</td>
</tr>
<tr>
<td>27-Dec-13</td>
<td><strong>12.592</strong></td>
</tr>
</tbody>
</table>

Total: 14 flood fatalities
Total: 7 fatalities during extreme regional rainfall

**Figure 5.2-2 (a)** 5-day average rainfall for the South West and recorded flood fatalities.

Extreme rainfall has a rough annual cycle, with summer and winter peaks. Fatalities occur randomly throughout the period. Half of the fatalities in the region can be partially explained by heavy regional rainfall. Multiple fatalities in the summer of 2007 did not occur in the context of exceptional rainfall for the region.
Chapter 5  

Fatalities and Their Floods

<table>
<thead>
<tr>
<th>South East flood fatality publication dates</th>
<th>5-day average rainfall on the date of publication (Bold indicates 95th percentile rainfall ≥6.66mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>06-Feb-01</td>
<td>5.804</td>
</tr>
<tr>
<td>03-Jan-03</td>
<td>11.258</td>
</tr>
<tr>
<td>05-Jun-08</td>
<td>3.86</td>
</tr>
<tr>
<td>30-Apr-12</td>
<td>9.444</td>
</tr>
<tr>
<td>07-Jan-14</td>
<td>8.41</td>
</tr>
<tr>
<td>11-Jan-14</td>
<td>2.818</td>
</tr>
<tr>
<td>Total:6 flood fatalities</td>
<td>Total: 3 fatalities during extreme regional rainfall</td>
</tr>
</tbody>
</table>

**Figure 5.2-1 (b) 5-day average rainfall for the South East and recorded flood fatalities.**

Extreme rainfall is patchier in the South East and long periods of heavy rain are less common (this is indicated by the large number of light blue daily rainfall peaks, individual rainy days are smoothed out by the average). Fatalities are spread out throughout the period and occur in winter, spring and summer. As with the South West, only half of the flood fatalities were reported during particularly rainy periods for the region, another three happened during dryer 5-day periods.
Central England flood fatality publication dates | 5-day average rainfall on the date of publication (Bold indicates 95th percentile rainfall ≥5.48mm)
--- | ---
26-Oct-04 | 3.124
26-Jun-07 | 8.804
28-Jun-07 | 8.182
29-Jun-07 | 3.884
30-Jun-07 | 4.428
19-Jan-08 | 6.408
29-Jun-12 | 2.662

Total: 7 flood fatalities
Total: 3 fatalities during extreme regional rainfall, and two more close to those dates

**Figure 5.2-2 (c) 5-day average rainfall for the Central England and recorded flood fatalities.**

Central England is the driest region in the analysis with the lowest 95th percentile rainfall value. Several deaths from flooding in this region occurred during the summer 2007 flooding. Here we see only two fatality report dates matching days of high rainfall, however, this is likely to be an artefact of the method. Using report dates rather than closest dates of death allows the data to be spread and visible on the date axis. However, whilst the death reports of the four June 2007 casualties may have come from different publications on separate days, the actual deaths may have happened on the same or two consecutive days. The raw data confirms that rainfall had been in the 95th percentile for the region every day between the 24th and 28th of June, suggesting that all four June deaths could be explained by extreme rainfall in the region. In this case, taking the 5-day average rainfall is not sensitive enough to reflect the relationship of the two datasets.
North West and Wales flood fatality publication dates | 5-day average rainfall on the date of publication (Bold indicates 95\textsuperscript{th} percentile rainfall ≥5.48mm) | North West and Wales flood fatality publication dates (contd.) | 5-day average rainfall on the date of publication (Bold indicates 95\textsuperscript{th} percentile rainfall ≥7.99mm) |
--- | --- | --- | --- |
30-Oct-00 | 12.814 | 21-Nov-09 | 12.222 |
14-Dec-00 | 8.01 | 23-Nov-09 | 9.62 |
04-Aug-01 | 1.962 | 30-Nov-09 | 5.042 |
28-May-02 | 2.324 | 18-Jan-11 | 4.366 |
31-Jan-04 | 9.398 | 07-Feb-11 | 11.112 |
09-Jan-05 | 7.104 | 27-Dec-11 | 3.754 |
10-Jan-05 | 6.23 | 28-Dec-11 | 3.55 |
11-Jan-05 | 6.118 | 28-Sep-12 | 13.246 |
28-Jun-07 | 9.124 | 29-Sep-12 | 6.588 |
29-Jun-07 | 6.098 | 30-Nov-12 | 2.998 |
09-Sep-08 | 10.098 | 26-Dec-13 | 6.484 |
30-Oct-00 | 12.614 | 28-Dec-13 | 3.058 |

Total: 22 flood fatalities | Total: 10 fatalities during extreme regional rainfall, and two more close to those dates |

Figure 5.2-2 (d) 5-day average rainfall for the North West England and Wales region and recorded flood fatalities.

The North West of England and Wales together are a relatively high rainfall region – third highest rainfall out of the six regions analysed. At the same time, extreme rainfall events here can be very severe; with the top 252 (5\%) of days raining heavier than 7.99mm for a 5-day average, events over 12mm and 13mm must be judged as very extreme (>160\% of the 95\textsuperscript{th} percentile value). The greatest number of reported flood fatalities (22, about a third of all flood fatalities for the period) can be geolocated in this region. Of these, 10 coincide with heavy rainfall days, and another two are most likely associated with these extreme rainfall periods.
Most of the flood deaths reported for the North East happened during the June 2007 floods, and all of these can be explained by heavy regional rainfall. A large number of peak rainfall events are not associated with any fatalities from flooding.
Scotland flood fatality publication dates

<table>
<thead>
<tr>
<th>Date</th>
<th>5-day average rainfall on the date of publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-Feb-02</td>
<td>9.05</td>
</tr>
<tr>
<td>31-Jul-02</td>
<td>10.74</td>
</tr>
<tr>
<td>07-Aug-02</td>
<td>2.002</td>
</tr>
<tr>
<td>10-Jan-05</td>
<td>13.65</td>
</tr>
<tr>
<td>27-Jun-07</td>
<td>6.13</td>
</tr>
<tr>
<td>24-Apr-10</td>
<td>2.042</td>
</tr>
<tr>
<td>18-Jul-11</td>
<td>8.8</td>
</tr>
<tr>
<td>31-Jul-11</td>
<td>1.622</td>
</tr>
</tbody>
</table>

Total: 8 flood fatalities

(Bold indicates 95th percentile rainfall ≥9.16mm)

Total: 2 fatalities during extreme regional rainfall

Figure 5.2.2 (f) 5-day average rainfall for Scotland and recorded flood fatalities.

Scotland is the wettest region in the analysis, with the highest volume for the top 5% of rainfall days. However, most of the flood fatalities recorded in Scotland occurred during relatively low rainfall periods for the region. Fatalities are also quite broadly spread throughout the period, without any temporal clustering.
The analysis of 5-day average rainfall improves upon the first batch of time series by providing clearer visual association between rainfall peaks and fatality crosses, where such an association can be traced. Importantly, it shows that no fatalities were reported on dry days or no rainfall periods, supporting the link between rainfall and flood death with extreme rain as a flood precursor. This set of time series examines the [rainfall AND fatality] events: the coincidence of heavy rain and flood fatality. For most regions, the rate for these is around 50%, with about half of the regional flood fatalities reported during heavy rainfall periods. This is lower for Scotland (25%) and higher for the North East (100% of four reported fatalities). The next set of results examines the trend within this relationship.

5.2.3 Results set 3: Is there a relationship between rainfall intensity and casualties?

The third question for the analysis was is there a relationship between rainfall intensity and casualties, or avoided casualties? The hypothesis is that there is a linear relationship, with only the most extreme rainfall having a high association with flood fatalities, and most rainfall being associated with no flood death.

About half of the deaths in the database are deaths which occurred during periods of extreme rainfall, that is when intensity of rainfall fell into the highest 5% of all regional 5-day periods. This suggests that there is a relationship between rainfall intensity and death: the higher the rainfall the greater the probability of drowning. Such a relationship is intuitively credible, but the linearity of this relationship needs to be examined and visualised.

<table>
<thead>
<tr>
<th>HadUKP Region</th>
<th>Flood fatalities reported in each region</th>
<th>Flood fatalities explained by extreme regional rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>South West England</td>
<td>14</td>
<td>7 50% or SW</td>
</tr>
<tr>
<td>South East England</td>
<td>6</td>
<td>3 50% of SE</td>
</tr>
<tr>
<td>Central England</td>
<td>7</td>
<td>3 (5) 43% (71%) of CE</td>
</tr>
<tr>
<td>North West and Wales</td>
<td>22</td>
<td>10 (12) 45% (55%) of NW&amp;W</td>
</tr>
<tr>
<td>North East England</td>
<td>4</td>
<td>4 100% of NE</td>
</tr>
<tr>
<td>Scotland</td>
<td>8</td>
<td>2 25% of S 48% (54%) of total</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>29 (33) 48% (54%) of total</td>
</tr>
</tbody>
</table>
For the purposes of this analysis, the rainfall days in all of the regions were broken down into intervals (bins) of 3mm per day, averaged over a 5-day period. This assessed all of the regions on the same scale, although rainfall intensity varies between regions, with the 95th percentile between 5.5mm in Central England and 9.2mm in Scotland, with the average 95th percentile threshold at 7.5mm. The relationship for all regions at all levels of rainfall seems to be linear.

Figure 5.2-2 Average deaths per day in all regions, by rainfall intensity range:
The highest bars (9≤15mm) reflect the most intense rainfall in all of the regions. This suggests the relationship between heavy rainfall and death from flooding is linear – the more rain, the greater possibility of flood fatality. The lowest four bins of rainfall intensity represent just under half of the flood fatality days in the database. The highest bin – 21mm and above – represents over half of the remaining casualties.

Caveats associated with this form of analysis include the frequent question of deriving averages from a very small sample of categorical death statistics. All deaths were subject to circumstances, and so inferring trends at low values is somewhat speculative. Nevertheless, the analysis suggests that there is nearly 5% chance of a fatality when daily total accumulated rainfall is above 12mm, which represents a very stark finding. And before making this claim, we need to apply some sensitivities to the model.

Firstly, we need to confirm that our numerical bins of rainfall intensity are relevant. It is clear that most 5-day average periods are dry or experience less than 3mm of rainfall. Fewer 5-day average periods fall into each next interval, with 5% of days represented by almost four bins in the analysis. Figure 5.2-3 shows that rainfall intensity has a very skewed distribution.
Most days have less than 6mm of rainfall. The average 95th percentile threshold is 7.5mm. Therefore, the four highest bins represent less than 5% of days in the period.

**Figure 5.2-4** visualises how average deaths per day are distributed between rainfall intensity intervals (bins). Plotting a line of trend suggests that there is a very weak relationship between rainfall intensity and death ($R^2 = 0.0184$). Deaths certainly increase over the 95th percentile threshold, as we know from the previous set of results in 5.2.2, but beyond this threshold the relationship is heavily skewed by the large number of deaths in North East England and Wales (15 cases in the 6≤15mm interval, versus 7 cases at lower rainfall intensities). The low $R^2$ is also driven by the inclusion of the highest intensity intervals (15≤18mm and 18≤21mm) which only represent a handful of days in the period (29 and three 5-day average periods respectively, across six regions).
Figure 5.2-4 Deaths in each rainfall intensity bin:
There seems to be a weak relationship, which is linear but not proportional. Average deaths do rise with rainfall intensity; however, the most intense periods report no deaths. This could be an artefact of the data: the highest intervals represent only 132 days of the period across six regions. It could be speculated that at higher frequencies, these intensities could yield higher casualties. But in its present state, the model seems to be skewed by the final two bins of rainfall intensity.

Adding further sensitivity to the model can be achieved by removing the highest interval. Rainfall over the 15mm threshold occurred only on three occasions over the 15 year study period, and only in Scotland. This outlying data point skews the results and does not represent any fatalities. Excluding it improves the strength of the relationship ($R^2 = 0.179$), but it still cannot be seen as proportionate.
Figure 5.2-5 Deaths per day in intensity bins, with the last bin removed:
The sensitivity adjustment suggests there is a relationship between intensity and numbers of deaths. However, speculating on the strength of the relationship is still difficult. If there were many more intense rainfall days in the top intervals, would the line of trend keep rising? Or would we observe a plateau because in fact very intense weather keeps people indoors and out of arms way (until, of course, the hazard intensity threatens buildings and lives therein).

The analysis of trend between deaths and high rainfall suggests that there is a weak relationship, which can be traced but not confirmed within such a small sample. If the average deaths per day statistic is interpreted as a probability of death, then we can conclude that there is a greater risk of death during the most intense rainfall periods. However, this would be a very fragile claim in the context of a small sample and a very low frequency of the most intense rainfall events.

An important observation, is that the highest intensity intervals did not report any casualties. This is primarily explained by the numbers being very low. If the UK experienced more extreme weather and we looked at a larger sample of 5 day periods with over 12mm of rain falling over an entire region, then we would probably see a greater number of casualties. However, in practice we know that much more localised and higher rainfall causes dangerous floods, and 12mm cannot be interpreted as intense rainfall at catchment scale.
At the same time, if we look at the whole regional intensity spectrum, the absence of casualties at the highest intervals is in itself an interesting observation. With most victims dying outdoors (as will be discussed in 7.3.3), the most extreme rainfall keeps people indoors and out of harm’s way. Perhaps this explains why the highest intensity bins did not lead to casualties, and that people’s choices and behaviours are the predictive factors of risk and safety: choices which will be explored in detail by Chapter 7. This might be true up until a threshold: major catastrophic events of high intensity impact would definitely lead to multiple casualties; however this has not been observed in the UK since 1953. These suggestive behavioural dimensions will be elaborated upon in the following chapters.

In conclusion, the analysis of this third set of results demonstrates a relationship between rainfall intensity and flood death, but this relationship is weak, and cannot be seen as causal because of its sensitivities and the underpinning sample size. Moreover, it cannot be interpreted outside the context of “innocent” rainfall events – high intensity rainfall events which are not associated with any fatalities. The next set of results examines these “safe” but extreme events.

### 5.2.4 Results set 4: How much extreme rainfall is not associated with any fatalities?

<table>
<thead>
<tr>
<th>Extreme rain</th>
<th>Flood fatality</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>✔✔</td>
<td>☒</td>
</tr>
<tr>
<td>No</td>
<td>☒✔</td>
<td>☒ ☒</td>
</tr>
</tbody>
</table>

The final question for analysis asked how much extreme rainfall (95th percentile) is not associated with any fatalities? The hypothesis was that most extreme rainfall is “innocent”.

The most evident feature of the graphs in the first two sets of results, is the degree of noise in the rainfall data. There are many rainfall days and 5-day periods and a great majority of them is not linked to any flood event, let alone a flood casualty. However, with over half of the fatalities occurring on days of over 12mm accumulated rainfall, it becomes important to know the scale of extreme (95th percentile) rainfall which was not associated with a fatality, and whether this scale has any regional pattern. Analysing these “innocent” extreme rainfall events, or “misses” in terms of the matrix, when no fatalities occurred, proves that extreme rainfall events and associated floods pose a low risk to life in the UK.
On seven occasions, a regional peak rainfall period in the South West coincided with a flood fatality in the region. During another 267 extreme rainfall 5-day periods there were no flood casualties. Visual analysis shows that there are clusters of extreme rainfall periods around late 2000-early 2001 and early 2014. A flood casualty is reported during both these periods. There are other clusters in safer periods, but none are as high and as frequent (darker sections) as these cases. Overall, there are substantially more “innocent” rain period than those coinciding with fatality (97.4%).

Figure 5.2-6 (a) Peak rainfall events (5-day average) and flood fatalities for the South West.
Figure 5.2-11 (b) Peak rainfall events (5-day average) and flood fatalities for the South East.

Extreme regional rainfall for a 5-day period coincided with a reported flood death on three occasions in the South East. Another 271 of the most rainy 5-day average periods for the region were not associated with a flood casualty. Two linked fatalities (early 2003, early 2014, from Figure 10b) can be seen to present during clusters of heavy rainfall (darker segments). The other (April 2012), is not associated with a cluster. Other peaks are spaced out more randomly, with little clustering apart from late 2000, but the only casualty around this date happened during a drier period. The second highest peak in the summer of 2008 looks close to the reported casualty, but is in fact a few weeks apart. The proportion of “innocent” rain period than those coinciding with fatality is similar to the South West result (98.9% “innocent” rate).
The results for Central England region are very similar to the South East, which can be explained by the fact that the same major flood events affected both regions, and caused death tolls. However, the rainfall coinciding with fatality events are different for this region (July 2007). But visually we can associate a few of the fatality crosses with clusters of high rainfall. This may suggest that the precursor period is longer than the 5-day window taken for an average, as accumulation and saturation processes combine to lead towards flooding. Due to the same number of matched dates, the “innocent” / "coincident” proportion is the same as for the South East (98.9% no coincidence with fatality).
As mentioned previously, the North West of England and Wales combined had the highest number of reported flood fatalities, and similarly, and perhaps in proportion, the highest number of rainfall and fatality coincident events (9) and lowest number of “innocent” rainfall days (265) from the 5% of the most rainy five day average periods. In fact, this proportionate increase may support the hypothesis that coincident events are random, as they are only increased by the number of analysed incidents. For this region, there are several high rainfall clusters which are not associated with a fatality cross (late 2002, late 2005, early 2008, etc.). Some of the nine coinciding events are within clustered periods (for example late 2008), others are more randomly spaced. Overall, the increased number of coinciding events and clusters makes visual association more difficult and causes the time series to look more noisy and scattered. The proportion of “innocent” rain period events to those coinciding with fatality is slightly lower with a 96.7% “innocent” rate, but the overwhelming number of high rainfall events which do not lead to flood fatalities (and most likely do not lead to floods at all) is still evident.
There were four flood fatalities in the North East, all of which coincided with extreme rainfall, as described in the previous sections. Three of these are represented by the thick cross in July 2007, as three reported deaths on consecutive dates are overlaid. The rainfall here shows some clustering (thicker bar), but not as much as in other high rainfall periods for this and other regions. The same can be said of the spring 2010 casualty – some thick bars of peak rainfall are observed, but this is not a long series of high rainfall. There is generally less clustering of high rainfall for this region and the ratio of “innocent” rain events to those coinciding with fatality is high (98.5% “innocent” rate).

Figure 5.2-91 (e) Peak rainfall events (5-day average) and flood fatalities for the North East.
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f)

Figure 5.2-101 (f) Peak rainfall events (5-day average) and flood fatalities for Scotland.

As the wettest region in the analysis, Scotland displays some of the highest peak rainfall bars. However, there are only two flood fatalities reported on high rainfall dates, and visual analysis shows that the fatality crosses are spread out without particular association with a clustering of rainfall peaks. Many present in gaps or more spread out areas. Clusters of high rainfall in late 2006 and late 2014 are not associated with any fatalities from flooding. This may be explained by the fact that high rainfall in Scotland is not always a precursor of flooding, often due to the mountainous nature of the terrain. In summary, there are many more “innocent” rain events than those coinciding with fatalities, with a 99.3% “innocent” rate.
This analysis clearly shows the number of “safe” heavy rainfall events in all regions. The overwhelming majority of peak rainfall incidents are not associated with a flood casualty, whether because no flood conditions were caused by these events, or because the resulting flood did not cause fatal impacts. The analysis proves that most extreme rainfall events in the UK pose little danger to life. However, the periods of clustered high rainfall are interesting, both as “innocent” events and as those coinciding with fatality. They do not seem to return any short term patterns, but do coincide with known high impact flood events (2007, 2012, 2014).
5.3 Discussion: combining the results

Looking at the four sets of analyses and time series a number of conclusions can be reached. Firstly, no flood fatalities were reported during dry periods: although this is an obvious result, it is important in proving the usability of the method. A degree of association between extreme regional rainfall and death from flooding can be observed, with about half of the casualties occurring during the highest rainfall intervals. However, the relationship is weak since between 28 and 32 flood deaths happened outside of the peaks of 5-day average periods of intense rainfall. The findings suggest that there is a greater relative risk of death at higher regional rainfall intensities, but the base rate remains low: 1.7% (29 days of extreme rainfall and fatality, versus 1616 “innocent” rainy days).

Secondly, as the second set of time series shows us in 5.2.2 (Results set 2: Was the rainfall extreme when fatalities occurred?), about half of the reported flood fatalities are, in the least illustrated and at most explained, by heavy regional rainfall in the preceding 5-day period. The certainty of this conclusion is slightly limited by the method – the 5-day average can be seen as either too short or too long to attribute flooding and account for ground saturation, the reported dates are not precisely the dates of death. However, on the whole this seems to be a reasonable result, which is an improvement on the pilot study, where only a third of fatalities matched the region and time of a major flood reported by the MetOffice extreme weather summaries. This result can be used to conclude that around half of the victims died in surface water floods which were triggered by extreme rainfall (29-34 people between 2000-2014). However, the other half died in other types of localised flooding which was not triggered by regional extreme rainfall, but was likely to have been smaller scale, more localised, and therefore potentially less predictable. The temporal and regional distribution of these rainfall triggered fatal flood incidents is quite random throughout the study period. This can be seen in the proportional increase between regions: comparing 14:7 coinciding/innocent rainfall cases in the South West to 22:10 (22:12) in the North West and Wales suggests that the number of coinciding cases increases proportionately with the number of cases for investigation. This suggests that the occurrence of coincidence with fatality is random.

Thirdly, and most importantly, the time series (specifically, set 4, Figure 5.2-11) clearly demonstrate that there is a very large number of significant regional rainfall events, which are not associated
with flood fatalities, and possibly not associated with any flooding. As with the death toll itself, we are examining a very low number of random tragic accidents which present no spatial or temporal pattern, merely an agglomeration of circumstances. The vast majority of heavy rainfall in the UK does not pose a risk to life.

Table 5.3-1 Combined results of rainfall and fatality analysis: About half of the reported fatalities can be explained by extreme regional rainfall averaged over five days prior to the casualty report. The majority of high rainfall days do not lead to flood casualties. NB: “✔✔” in parentheses represent reported deaths which do not match extreme rainfall by report date, but could be attributed to a preceding high rainfall period.

<table>
<thead>
<tr>
<th>HadUKP Region</th>
<th>Flood fatalities reported in each region</th>
<th>Fatalities explained by extreme regional rainfall (✔✔)</th>
<th>Highest 5% rainfall 5-day periods not linked to a fatality (“✘✘”, max. 274)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South West England</td>
<td>14</td>
<td>7</td>
<td>267</td>
</tr>
<tr>
<td>South East England</td>
<td>6</td>
<td>3</td>
<td>271</td>
</tr>
<tr>
<td>Central England</td>
<td>7</td>
<td>3 (5)</td>
<td>271</td>
</tr>
<tr>
<td>North West and Wales</td>
<td>22</td>
<td>10 (12)</td>
<td>265</td>
</tr>
<tr>
<td>North East England</td>
<td>4</td>
<td>4</td>
<td>270</td>
</tr>
<tr>
<td>Scotland</td>
<td>8</td>
<td>2</td>
<td>272</td>
</tr>
</tbody>
</table>

Inserting these results into the matrix from Table 5.1-2 gives the following totals.

Table 5.3-2 Completed analysis matrix for rainfall and fatality data: Extreme rainfall, falling within the top 5% of regional rainfall intensity for the period, is not predictive of a flood fatality. Some fatalities coincided with extreme rainfall periods, others happened during light rain events. There were many heavy rainfall periods which did not lead to any casualties.

<table>
<thead>
<tr>
<th>Flood fatality</th>
<th>Extreme rain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Yes</td>
<td>✔✔</td>
</tr>
<tr>
<td>highest 5% regional rainfall 5-day average</td>
<td>29</td>
</tr>
<tr>
<td>No</td>
<td>✔</td>
</tr>
<tr>
<td>other regional rainfall intensity 5-day average</td>
<td>35</td>
</tr>
</tbody>
</table>
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Figure 5.3-1 Relative proportions of heavy rain and fatality occurring together:
There is a significant majority of “innocent” extreme rainfall events. Fatalities hardly feature in the context of rainfall events.

Considering the relative proportions of the four matrix quadrants, as presented in Figure 5.3-1, it is clear that the association between rainfall and fatality is not a strong one. Almost as many fatalities happened in the context of extreme rainfall, as during lighter rainfall periods, which means that it is impossible to conclude what type of flood event is more associated with fatalities – flash or riverine. We can conclude, however, that for the UK during the study period, meteorological conditions have not been predictive of flood casualties, beyond the simple, but still important observation that nobody drowned in a flood on a dry day.

Death from flooding in the UK is rare and seemingly random, sometimes (half the cases) preempted by extreme regional rainfall, less often (a third of cases) attributed to the most dangerous events which spark interest on a national scale. The remainder are consequences of localised flooding, with a small spatial footprint, possibly triggered by intense rainfall on a local scale, and therefore presenting as rapid and intense. The latter is a speculation based on the absence of evidence for regional scale impact, but proof of extreme rainfall as a precursor to intense flooding.
5.4 Conclusion: the limited impact of rainfall

By assessing the potential of rainfall records to predict the occurrence of a flood fatality in the dataset, the analysis in this chapter addressed the research question:

- Who is dying from flooding in the UK? And are these the people we expect?

Testing all four hypotheses of extreme rainfall predicting flood death shows that for the UK, rainfall intensity does not explain fatalities from flooding, at least not all of them. Overall, the pattern of fatalities does not match the pattern of rainfall events, and therefore the resulting pattern of surface water flooding, very closely. Testing the last hypothesis, that most rainfall events are not associated with any casualties, we can prove that although as many as half of the fatalities happened during high intensity events, overwhelmingly almost all intense rainfall events passed without fatalities.

The circumstances of death are important, and the analysis provides some interesting observations on the rainfall context of roughly half of the reported flood fatalities. For the rest, we have to speculate whether the event was intense and rapid or slower and more predictable. The only conclusion we can draw about the unmatched half of the cases, is that the events were highly localised and not caused by regional scale rainfall. Therefore, we cannot draw conclusions similar to those drawn by Ruin et al. (2008) about the morphology of a deadly flood. In the UK, floods with a death toll are varied in spatial and temporal footprint, and appear as essentially random events.

Partly this can be explained by the fact that the UK enjoys comparatively mild weather. Chapter 1 has already identified this as the main reason for the low rate of fatalities and few multi-fatality events in the UK. It also seems to be the reason we cannot make clear conclusions about the profile of a deadly flood: there are, thankfully, not enough cases to observe obvious patterns.

Extreme weather events (flood inducing), important at a national scale, explain less than a third of the fatalities, based on those reported as significant and extreme by the MetOffice. So two thirds of reported fatalities happened during floods the MetOffice does not see as worthy of reporting in this format. Rainfall patterns only partially explain flood fatalities in regions in about half of the cases. The other half would have to be examined at a closer level, as each death was much more localised.
Another reason for the very low risk to life from extreme rainfall events may be that the UK population is well protected with good investment and warnings, which might explain the high degree of no fatality incidents during extreme rainfall. Although Scotland has weather hazards that are more frequent and more severe, it also had the fewest extreme rainfall events coinciding with fatalities. We can only speculate why this might be. One reason might be a highly efficient and well respected warning and prevention structure. At the same time, it might also be explained by sparse population located out of the passage of many hazardous events. Nevertheless, the small trickle of fatalities through the period illustrates a situation wherein increased levels of protection are facing diminishing returns, preventing death systematically but not completely.

Therefore, overall, we can conclude that the flood events that kill are more or less random: they have no temporal pattern or major seasonal trend, they cannot be classed as regional or local in extent (split precisely in half), and they can only partially be explained by extreme or hazardous rainfall.

We can also conclude that there is an overwhelming majority of serious but “innocent” events, when no flood fatalities occurred. The risk to life posed by extreme rainfall is negligible. This could be explained by geographical and social factors (where events happen versus where people are present). However, it could also be a result of an efficient and protecting warning and protective forecasting system. Chapter 8 will investigate this in more detail.

Analysing which days are more likely to match a reported flood death, there is a pattern that suggests that the most intense regional rainfall periods (95th percentile 5-day average rainfall), especially when rain is over 12mm, more flood deaths occur. There is a weak linear relationship, the number of observations is very low, skewed by categorical intervals and single region results. A relationship exists, but cannot be seen as causal, and may be very different at greater scales.

In conclusion, the analysis demonstrates that there is a high degree of chance associated with the fatal flood incidents, which cannot be fully explained by the intensity of a rainfall precursor at a regional scale. With most deaths occurring as single isolated incidents, a meteo-hydrological analysis of the causes of flood death, similar to the studies in the Gard region of France developments of the approach for the US (Ruin et al., 2008; Terti et al., 2015), does not make sense for the UK, at least not for any flood events in recent decades. At regional scales, no clear patterns
between rainfall and flood death could be identified. Instead, we can try to look for other patterns in the death cases, focusing on similarities in the circumstances of death. Perhaps the victims can be grouped by their actions and behaviours during the flood? Chapter 7 will address these aspects. But first, could there be a geographical explanation to flood death? Are there patterns or clusters in the locations of reported deaths? The next chapter will present maps, analysis and discussion of the sites where victims were overcome by floodwaters between 2000 and 2014.
“The pair have reached that fearful chasm,
How tempting to bestride!
For lordly Wharf is there pent in
With rocks on either side.

This striding-place is called THE STRID,
A name which it took of yore:
A thousand years hath it borne that name,
And shall a thousand more.”

- William Wordsworth, from “THE FORCE OF PRAYER; OR, THE FOUNDING OF BOLTON PRIORY”

The course of the river Wharfe forms part of the border between North and West Yorkshire. At the very south boundary of the Yorkshire Dales National Park, as it passes Bolton Abbey, the river narrows to the width of a stride and deepens dramatically. This is The Bolton Strid; a rapidly flowing section of the Wharf, which has claimed so many lives over the centuries, it has become a subject of legend and fiction (Shoe 2016, New York Times). In his poem “The Force of Prayer, or, The Founding of Bolton Priory” Wordsworth imagines a young boy and his greyhound, bounding across the Strid unsuccessfully, albeit “for the hundredth time”. The tragic accident is commemorated by his grieving mother in the building of the abbey priory in 1115. This is a story echoed in many entries of the fatalities database, where victims crossed familiar fords, streams and fields, only to be caught out by unfamiliar conditions. In mid-October 1998 the Strid claimed the lives of a couple on their honeymoon (BBC News, 1998); their bodies were washed up several days later and several miles apart. A local resident who spotted one of the bodies said the high flow “looked like flood water”. Local observations are important for this type of data, and they are confirmed by recorded flow rates of 89 and 59 m$^3$/s at the next monitoring station downstream at Addington on the days the couple were presumed to have drowned, compared to the mean flow of 14 m$^3$/s $^4$.

$^4$ Historical flow data for the relevant stretch of the Wharf obtained from the National River Flow Archive, Centre for Ecology and Hydrology, Natural Environment Research Council (‘NRFA Station Mean Flow Data’, 2016).
Whist the Bolton Strid has been called “the deadliest stretch of water” by headlines, no fatalities were recorded here by the database for the period 2000-2014. There have been accidents here during the study period, notably the death of a 10-year-old boy in 2010, but none of them can be classified to have occurred under flood or extreme weather conditions.

Flood fatalities recorded by the database represent a variety of geographies – rural and urban, north and south, at various elevations, in water bodies of varied breadth or firmly on dry land. Crude analysis suggests that, according to the database, the “deadliest stretches of water” are found in North Wales and Shropshire, at least for the time period and type of accident in question. No specific water body features more than once in the database. Several factors might be at play here: firstly, the overall rarity of flood death; second, the length of the study period; also, the limited scope of the search which only takes into account drowning and asphyxiation under particular conditions.

The aim of this chapter

By analysing the incidents of flood fatality spatially, the chapter continues to answer the first two research questions:

- Who is dying from flooding in the UK? What is the socio-demographic profile of a weather casualty?

- Are these the people we expect to be vulnerable?

The chapter addresses these questions by mapping the incidents of flood death, where possible, analysing the regional distribution of fatalities across Great Britain, comparing the distribution of fatalities to the population density distribution, and looking for causal relationships between a fatality and its location. This analysis tests the following hypothesis: flood fatalities in the UK can be predicted by geographical markers of sparsely populated regions and rurality.

The flood fatalities database reports some geographical and contextual data, which can be used to investigate whether or not people in the UK die from flooding in the locales we might expect. The chapter maps flood fatalities against physical and human geographical factors and capture whether any of them might explain the pattern of flood fatalities.
6.1 Locations of UK flood fatalities 2000 – 2014

Mapping flood fatalities recorded in the database presented a number of challenges, which have left inherent imprecisions within the maps presented below. However, there are several interesting observations which can be drawn from the mapped visualisations of the geographical spread of fatalities.

First, it is important to present these observations in the context of the mapping exercise itself, and its methodological challenges. Newspaper reports are not the best sources of geospatial data: reports from local newspapers are more likely to mention details of the victim’s home location, their job and local ties than the precise place of their accident. Reporting on the same story, national press coverage has less interest in the local scale, and usually mentions the town or river, occasionally a landmark to contextualise the event. In this way, a victim’s body can be reported to have been found in “Bethesda, North Wales, on the edge of Snowdonia” by a national newspaper, and “in the stream behind her home in Nant Ffrancon, Bethesda, Gwynedd” by a local paper (reporting on Victim ID 201312.120). Overall, out of the 62 flood deaths, only 13 could be traced to a precise road, bridge, ford or water body where they died. For the remainder, the nearest village or town could be confidently assumed for 35 casualties, and 14 could only be identified to the level of the wider area or county. In total, almost 80% of the flood fatality incidents can only be mapped imprecisely.

Moreover, even when we can plot a fine-grained marker, it is unlikely to represent the point of death: the site of the asphyxiation which caused the death. For drowning in watercourses, it is impossible to determine where the asphyxiation occurred. The reported details may either provide location data on where the victim fell, or where the body was found, and the latter can be several miles downstream and much less relevant as it does not reflect the high risk site.

Deaths at home or in vehicles can usually be identified to the road scale, especially if local press publications are used instead of national reports. Although river basins can be inferred form the reports, they are never stated within them and such an exercise is unlikely to be very precise or particularly useful, especially given the fact that many deaths happened beyond the flooded watercourses, on roads and in basements.
With all these caveats in mind, it is worth remembering the overall scale of fatality. Each of the 62 flood deaths over the 15 year period has been identified within a UK local authority. However, maps of individual LAs and their flood fatalities produce very sparse visualisations and no possibility for tracing special patterns. The only scale at which visualisation becomes useful is the national scale, so the imprecision of the individual geolocations becomes less important. Overall, the maps represent death sites which are certainly plotted within the correct local authority, hence their boundaries provide a useful reference base map. At higher resolution, the variability in the spatial reporting starts to play a part, varying the data in quality from the nearest city to the specific bridge or street, and becoming even less precise for rural deaths amongst walkers in national parks. Therefore, the database cannot be used to generate a map of risk sites as precise as the observations of the Bolton Strid, but it can be used to map fatal flood incidents on the national scale to observe spatial patterns and skew.

On five occasions, newspapers reported multiple fatality flood events; in each instance two people died at the same location – these will be referred to as multiple fatality events. In each case, the victims were either family members or friends and died together: 1) in a submerged a car in Devon in 2000; 2) in a flooded house in Cumbria in 2005; 3) in a flooded basement in Tewkesbury in 2007; 4) in a flooded cottage in Merthyr in 2011; and, 5) in a swollen river after a dog rescue attempt in Wrexham in 2012. The nature of the incidents suggests that the spatial clustering of these deaths is a factor of the victims’ relationships, not of the flood’s geography. In other words, it is not an increased severity of hazard which claimed more than one life in the same location, but the temporal clustering of victims at the same point of impact. Therefore, these incidents are indicated by a separate symbol on the map, but the symbol is not differentiated by size so as not to suggest a greater level of risk.

Figure 6.1-1 presents a national (England, Scotland and Wales) map of flood fatalities reported in local and national print news from 2000 to 2014. Figure 6.1-1 shows the locations of fatalities which have been identified in the database as those directly caused by flood waters. The few deaths which were found in Northern Ireland were indirect or road deaths, and so did not form part of the final list of fatalities. Therefore, the visualisations in the following sections will present only maps of Great Britain.
Figure 6.1-1 Locations of flood fatalities, 2000 – 2014:
Crosses represent a flood fatality. Crossed circles indicate two deaths at the same location, all of which indicate pairs of people dying together during a shared activity, rather than multiple individuals affected by the same event. One incident of flood death could not be mapped and one is obscured by an overlaying marker. In total 60 geo located incidents of flood deaths can be seen in the visualisation. A slight skew towards the west of Britain can be observed from this visualisation, with particular clusters in the west of England, north and south Wales.
Looking at Figure 6.1-1, few clear geographic patterns can be observed, and even fewer explained. Flood fatalities seem to have occurred in most areas of the country, besides East Anglia, Scottish Borders and west and central areas of the Highlands. However, considering the physical and population geography of Great Britain, the explanation for this cannot be straightforward. For example, remoteness and sparse population can explain the relative safety of the Highlands and Norfolk; fewer people means lower rates of exposure. However, the same factor can be used to explain a certain level of clustering fatalities in north Wales and Cornwall, where remoteness equates to a distance from population centres and emergency services. At the same time, remoteness from population centres is unlikely to be a causal factor of either risk or safety, because qualitatively splitting fatalities into “rural” and “urban” events suggests an almost even split: 32 urban incidents (in towns, in or around houses, on roads) and 30 rural, or rather countryside, incidents.

Landscape and topography also prove contradictory. For instance, there is as much an absence of fatal incidents in the flats of the East coast as in the mountainous regions of Scotland. In Wales, the valleys of south Brecon and the north edge of the Cambrian mountains both exhibit some clustering of fatalities: there were five deaths recorded in both of these regions. Nevertheless, the map does present a traceable skew of fatalities towards the west of Britain, with particular clusters in Cornwall and in South and North Wales where multiple fatalities have occurred throughout the study period.

Table 6.1-1: Fatalities from Figure 6.1-1 split up by UK region. 37 out of 55 occurred in the Western regions and Wales, with an additional three cases in the west of Scotland.

<table>
<thead>
<tr>
<th>Region</th>
<th>Mapped flood fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>South East</td>
<td>5</td>
</tr>
<tr>
<td>London</td>
<td>1</td>
</tr>
<tr>
<td>East of England</td>
<td>1</td>
</tr>
<tr>
<td>East Midlands</td>
<td>3</td>
</tr>
<tr>
<td>Yorkshire and the Humber</td>
<td>5</td>
</tr>
<tr>
<td>North East</td>
<td>0</td>
</tr>
<tr>
<td>Scotland East</td>
<td>3</td>
</tr>
<tr>
<td>Scotland West</td>
<td>5</td>
</tr>
<tr>
<td>North West</td>
<td>6</td>
</tr>
<tr>
<td>West Midlands</td>
<td>3</td>
</tr>
<tr>
<td>South West</td>
<td>8</td>
</tr>
<tr>
<td>Wales</td>
<td>15</td>
</tr>
<tr>
<td><strong>East regions</strong></td>
<td><strong>18</strong></td>
</tr>
<tr>
<td><strong>West regions</strong></td>
<td><strong>37</strong></td>
</tr>
</tbody>
</table>
Although the western skew of fatalities can be visually observed, its scale and significance needs to be interrogated further. Measuring the fatality locations’ distance from a westernmost longitude reference allows assembling them along a descending west-east scale. The individual location points can then be sorted into bins and presented as a histogram.

**Figure 6.1-2 Fatalities’ westward skew:**
Measure of flood fatality location in terms of distance from the westernmost fatality (River Neet, Stratton, Cornwall, Victim ID 08.08.01). Point (.00) on the x-axis represents this most westward casualty as a nominal start point for the measurement (222914 easting, 106603, northing). The units of the x-axis represent UTM easting differences from this westmost casualty, in bins of 25,000m (see map inset). A clear westward skew can be seen from the steeper slope on the left.

The histogram in **Figure 6.1-2** shows a steeper slope on the left of the graph, indicating that fatalities were recorded in the west section of the map at a greater frequency. This steeper western slope, which can be
seen from the chart, confirms the skew. The fatality furthest west reported for the 15 year period was of a five-year-old girl drowned in the swollen River Neet, whilst playing with her dog in Stratton, Cornwall in August 2008 (victim ID 08.08.01). The nearest XY coordinates to the reported point of death are mapped as (222914, 106603) – this fatality is represented in the first column of the histogram. The other columns include fatalities, with easting values less the Stratton value (Lat_distance = x – 222914).

Analysis showed that distances from the Stratton point (0.00) ranged between 2069 (min) and 315698 (max), \((M = 123366; SD = 80929.5)\) for the 62 location points analysed (including those with multiple fatalities). Taking the middle distance value of 157,849, it can be seen that 40 location values fall west of this point, 22 are east. This represents roughly 65% of all fatalities recorded located in the western part of the study area. Results show that while the locations are non-normally distributed, with skewness of 0.563 \((SE = 0.304)\) and kurtosis of -0.641 \((SE = 0.599)\), the skew statistic is not strong enough to explain the overall westward trend of the map of fatalities. However, for the 40 west side fatalities \(t = 10.53 (p < .001)\) and for the 22 east side fatalities, \(t = 5.79 (p < .001)\); the difference of means shows that the west trend is a significant pattern.

It is important to consider why deaths are reported in the Western regions at a higher frequency. Several factors might explain this trend. The west coast of Britain experiences more severe rain and weather due to the impact of Atlantic weather systems; surface water flooding might be more sudden due to higher intensities of rainfall. In addition, areas of North Wales and Cornwall, where a significant number of fatalities happened, are remote and sparsely populated: there is less help around, more vigilance and preparedness is assumed on behalf of locals, and the response of emergency services may be inhibited by distance and ease of access, even though successful emergency response operations have been conducted after events like the Boscastle flood of 2004. Many locations in the West of Great Britain where fatalities occurred are remote areas of natural beauty, where victims were taking part in recreational outdoor activities, including hiking and water sports. Such incidents were reported along the River Usk, River Dart, in Conwy, Gwynedd, Shropshire, Dartmoor, and other remote or rural locations. Remoteness relates to a decreased degree of protection, as well as an increased likelihood of risk taking behaviours as part of outdoor
activities including, but not limited to, canoeing, swimming, hiking, exploring waterfalls, crossing fords, etc.

For floods in the South West, we can see some clustering of fatalities around Gloucestershire, which are almost exclusively explained by three deaths in Tewkesbury in July 2007. Some larger events, like Sheffield in 2007, cause clusters around particular locations which are only relevant to specific years.

Similarly, to the temporal trend, there is no clear geographical trend that can be observed from the flood fatalities identified in the database. Visual inspection shows no clear pattern of clustering in terms of location of fatalities. An overall westward skew can be partially confirmed statistically. In order to understand any causal relationships and similarities between places where people have died, we need to look deeper, overlaying some demographic and population factors onto the fatalities map.

6.2 Fatalities mapped against population distribution

The previous section has established that flood fatalities in the UK have a slight western skew in terms of their geographical distribution, but show no obvious spatial clustering. How might this distribution be explained?

It might, for instance, be a function of the underlying population distribution. Disaster risk reduction teaches us to assume a greater degree of risk in areas of higher exposure. Vulnerability fits into this model of analysis both as context and outcome vulnerability, for example in the exacerbated susceptibility due to the socio-economic correlates of high density living. For flash floods, the urban environment, with its limited ground permeability and the feedback effect of blocked drainage, can be seen as increasing the risk of death from flooding. Hence, a high level estimate might suggest that the pattern of flood fatalities roughly follows the pattern of population distribution.

Using a list of key words from the newspaper articles in the database, definitions of “urban” and “rural” environments were manually derived for the sample. Flood fatalities were coded as urban where the report mentioned them occurring near or in buildings, culverts, or drains; broadly within towns and cities; or whilst driving on A class roads or higher. Flood fatalities were coded as rural
due to descriptions of national parks, forests or remote wilderness areas; incidents which feature fords or streams flooding minor class roads or country lanes; incidents where no nearby street address could be identified.Crudely dividing incidents of flood death into rural and urban, shows that 52% of flood fatalities occurred in a broadly urban environment, and the rest can be classified as “rural”. This fairly even split between “urban” and non-urban casualties can be further explored by mapping fatality patterns in the context of urban population patterns, as demonstrated by Figure 6.2-1.

At this stage, we move onto analysing the geography of flood fatalities based on Local Authorities (LAs) as a unit. The reason for this is two-fold. Firstly, most available data is reported on an LA level, and whilst regions and clusters have multiple definitions, the 418 district, county and unitary principal authorities in the UK provide a standard classification system. Secondly, the LA scale is used across disaster risk management: The Flood Forecasting Centre classifies warnings by LA, for example. By applying this method of classification, the flood fatality study maps onto the same scales as used by operational authorities with statutory responsibility for protecting life.

For the purposes of this study, 380 Local authority areas in Great Britain were considered, and each centralised dataset was cleaned and filtered to match the selected units. 380 LAs are a result of capturing 31 councils in Scotland, 22 councils in Wales, and 326 district and unitary authorities in England. County councils, unless unitary, were excluded, the Isle of Wight and Isles of Scilly are excluded due to mapping protocols, and Northern Island is excluded due to the absence of fatal incidents reported there for the study period. Overall, no flood fatalities occurred in the excluded areas.
Figure 6.2-1 Flood fatalities 2000-2014 plotted on a heat map England and Wales population density (2011):
Colour saturation represents residents per square kilometre mapped by Local Authority areas, as signified by the key. Few flood deaths have occurred in major population hubs.

A visual analysis of Figure 6.2-1 observes that, unlike the initial hypothesis, informed by exposure and vulnerability theory, most flood fatalities seem to occur outside major population density clusters, in areas with lower population density for England and Wales. Overall, deaths from flooding occurred in 46 local authority (LA) areas over the 15 year period, with nine LA’s reporting two deaths and four LA’s reporting three fatalities (five of these instances were concurrent deaths,
see Section 6.1, page 140). This is a small fraction of the 380 local authorities presented on the map in Figure 6.2-1.

Given that the geographical spread of LAs with flood fatalities seems to lack any sort of visual pattern, it is interesting to see whether these 46 areas have spatial or geographical attributes in common, perhaps indicating that there are certain factors predicting the risk of death from flooding in a particular location, or type of location. The first variables to consider are LA size, population size, and density.

Is the size of a local authority, whether area or total population, a predictor of a flood casualty within its borders? All other variables being equal, larger areas might experience a greater frequency of death, simply by virtue of size, and hence number and variety of watercourses and hazardous locations. Predictions for the correlation of population size and density with the occurrence of a flood fatality are more complex. On the one hand, large populations increase exposure and may be coupled with exacerbating socio-economic parameters. On the other hand, if the rurality of flood fatality risk is taken into account, population centres and densely populated urban areas might be less likely to report casualties. This seems to be illustrated by Figure 6.2-1 but needs further confirmation through calculating correlations and regression analysis.

The occurrence of fatalities in LAs of various area and population size can be visually represented by charting the scale of authorities and highlighting those in which a flood fatality has been reported.
Figure 6.2-2 Chart of LAs by size (hectares):
Blue bars represent 45 LAs with flood fatalities in the period 2000-2014. Highland, where one flood death is reported, is excluded due to its vast area (>2.5m ha). There is a noticeable visual skew towards larger LAs, as the fatality hue is stronger towards the right side of the chart.

Figure 6.2-3 Chart of LAs by population size:
Blue bars represent 46 LAs with flood fatalities in the period 2000-2014. There is a small clustering of fatalities amongst the most populous LAs. The other fatalities are spread out evenly throughout the dataset.
Although visually, the blue bars seem to occur more frequently towards the larger end of the LA size scale, this needs to be confirmed by performing a regression of the size and population variables. For additional depth of analysis, a population density figure was used, based on the area and ONS datasets.

A regression was calculated to predict flood fatality occurrence based on LA area size, population size and population density. A significant regression equation was found ($F(3, 375) = 12.899, p < .0001$), with an $R^2$ of .094. Area in hectares was a highly statistically significant predictor ($p < .0001$) of flood fatality occurrence. Population size was also slightly significant as a predictor variable ($p < .005$) in the regression model.

Secondly, a Pearson correlation was computed to confirm the regression analysis and assess the relationship between local authority attributes and the occurrence of flood fatalities within them.

Table 6.2-1 Results of Pearson correlation computation for LA attributes\(^5\) and flood fatality risk: There are no strong correlations. The strongest correlated variable out of the three tested is LA area in hectares, which has a weak and significant positive correlation to the occurrence of fatalities.

<table>
<thead>
<tr>
<th></th>
<th>Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Pearson Correlation</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Population</td>
<td>Pearson Correlation</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Area (hectares)</td>
<td>Pearson Correlation</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
</tr>
<tr>
<td></td>
<td>N</td>
</tr>
</tbody>
</table>

*significant at the 0.05 level  
**significant at the 0.01 level

There was no correlation between flood fatalities and population size ($r = .092, n = 379, p = .073$).

A small, slightly significant negative correlation was found between LA population density and flood fatalities ($r = -.110, n = 379, p = .032$); this may indicate towards, though not explain, the visual

---

\(^5\) Only 379 local authorities are included as four minor LAs do not feature in both population and density datasets. No fatalities occurred in these LAs.
pattern of the map, were fatalities plot away from population clusters. A more significant correlation is found between LA size in hectares \((r = .279, n = 379, p < .001)\), which may also partially explain the rural fatality (characterised by nature, minor roads or small settlements mentioned in the fatality report) located away from population centres, if we take into account the fact that authority size is negatively correlated with population density \((r = -.198, n = 379, p < .001)\). Overall, calculating the correlations shows that if there is a pattern of LA features and flood fatalities, it is not a strong one, and the only parameter that can predict some risk of flood fatality is the size (and hence, in part, the rurality) of the local authority.

Despite around half of fatalities happening in a broadly urban context, the map and statistical analysis prove that they rarely occur in the most densely populated areas. This may be explained by the same observations of remoteness and activity at the time of the fatal incident. It might also be explained by levels of flood protection in major urban centres.

Importantly, in analysing flood death vulnerability in the context of classical understandings of vulnerability, the map in Figure 6.2-1 and associated analysis can provide a commentary on exposure as a factor of vulnerability. Population density is typically classed as a factor increasing vulnerability through the increased number of households exposed to hazard, the greater likelihood of poverty and associated lack of resilience. In the case of England and Wales flood fatality risk, an opposite effect can be observed, with the highest population density reporting lower frequencies of flood death. This suggests that the risk of flood death in the UK is explained by factors other than contextual urban vulnerability through exposure and socio-economic factors.

**6.3 Conclusion: location versus context**

The chapter has attempted to further explore two research questions:

- Who is dying from flooding in the UK? What is the socio-demographic profile of a weather casualty?
- Are these the people we expect to be vulnerable?

The aim was to test whether the geography of flood fatalities is predictive, by using a subset of potentially “vulnerable” geographic parameters, including terrain, rurality, population size and
density. The tested hypothesis, encapsulating were we might find flood deaths in the UK, was that **flood fatalities in the UK can be predicted by geographical markers of sparsely populated regions and rurality.**

It is fair to say that overall signals can be clearly interpreted from the data, and geography alone cannot explain the reason for a fatal flood incident.

In terms of the overall geography where fatalities occurred, the western regions of Great Britain reported more fatalities during the study period, although the data used in this study cannot confirm whether more floods occurred in the west. This skew in the distribution of fatalities is not statistically significant, and can partly be explained by specific event contexts, such as the Tewkesbury flood of 2007 registering three deaths in the west. Moreover, in terms of compounding variables, we can trace the prevalence of deaths in the west to the activities undertaken by the victims. The next chapter will explore these behavioural factors in more detail, but we already know that a substantial portion of flood fatalities are associated with rural recreational activities. The number of remote regions, national parks and protected rural sites reporting deaths in the west of the country is illustrative of this trend. So in fact, whilst the geography of the west of the UK does not explain the flood fatalities, the activities in the west might.

Physical geography, in terms of terrain and elevation, clearly explains neither fatality risk or safety. With as few fatalities reported in the flats of east Anglia as in the mountains of Scotland, and equal scales of death occurring in the hills and the valleys of Wales, there is no geomorphological explanation to find. This supports the assumption that flood deaths don’t necessarily happen in the places we expect. Whilst intuitively we might suspect specific watercourses in terrain where waters are likely to rise rapidly, to increase the magnitude of hazard and therefore the likelihood of risk, this first systematic analysis of flood fatalities shows no evidence of increased mortality risk in such sites. Perhaps such evidence will emerge for a longer time series analysis with more data points. The very low frequency of flood fatalities makes it difficult to identify clear hot spots of increased risk.

But perhaps there is another explanation, if we think back to the Bolton Strid: although very dangerous in terms of its physical geography, these hazards are also well known and reported, which influences the behaviour of its users. Hence, whilst the stream has caused multiple fatality
events over the centuries, there has been no death reported here for the study period. In this way, geographical factors are mediated by social and behavioural parameters, rendering an analysis of death frequency moot, and demanding a more qualitative approach.

Indeed, it may be that flood fatalities are more likely to occur where we as observers, or the victims themselves, don’t expect them, potentially where defences are therefore absent and the users’ vigilance is lower. Such as a culvert in Sheffield, for example (case study discussed in at the start of the next Chapter 7), or a familiar ford in Shropshire (case study discussed in 8.1).

To add to this indication of a possible experience bias, we can consider the fact that no particular water course reported deaths on more than one occasion during the study period. This may indicate the relevance of catchment return periods, but is more likely to signal at the protective role played by preparedness. Using newspaper reports does not allow for tracing incidents to their origin water courses, so a thorough catchment level assessment of fatal risk is not possible with this dataset.

If physical geography factors do not explain flood death, perhaps more can be gained from exploring demographic patterns of exposure. The split between rural and urban context flood deaths is almost even. The exposure factor of the risk equation suggests that vulnerability can be increased both in the case of remoteness from help or protection and hence increased exposure (rural), as well as in the context of high population density (urban). Considering the ratio of rural to urban incidents (32:30), we can conclude that this factor of exposure has equal effects (or lack thereof) on the number of fatal incidents.

Looking at demographic data further, we can trace no influence of population size or density on flood death, at least not at the local authority scale of reporting. The only statistically significant relationship is between the area size of the reporting unit and the presence or lack of flood death within it. However, this overlaps with the rurality factor, as larger LAs are always the more rural ones, and even this relationship is not particularly significant.

Having explored a range of geographical factors and their relationship to flood death, it is not possible to conclude that people in the UK die due to the rainfall precursors of floods or their geographical presentation. Neither can we claim an influence of contextual vulnerability in terms of
physical exposure or population proximity. Investigating the geography of flood fatalities, whilst an important strand of analysis, has provided no strong basis for predicting death.

Due to the imprecise location of each fatality, all that can be concluded is the importance of the context of the fatal case study. Considered together with the nature of activity, the presence or lack of knowledge about danger, the proximity to help and rescue, the geographical attributes of each case study may yield better, if more qualitative explanations. Therefore, instead of looking at contextual vulnerability of the victims in situ, the next chapter will explore their rationalisations, decisions, and personal attributes which may or may not indicate their levels of behavioural exposure to the flood hazard.
Chapter 7 Risk and Behaviour

One of the most tragic cases in the fatalities database is that of 28-year-old Hull resident Michael Barnett (Victim ID 07.06.03). He dies of hypothermia in rising flood waters when his leg got stuck in the metal grate of a drain that he was attempting to clear at his place of work on the 25th June 2007. Despite efforts from all three emergency service providers, he lost consciousness neck deep in the fast flowing cold flood water. Bartlett made the decision to attempt the risky task of clearing the drain of debris to alleviate the flooding around it.

In May 2006 two amateur photographers decided to jump over the barrier an onto the sea wall at Blackpool pier to take photos of the storm waves. Both men, aged 23 and 33 (Victim IDs 06.05.01 and 06.05.02), were swept away by the storm and drowned at sea.

Linda Weir, 58, (Victim ID 10.04.01) lost control of her quad bike and during a localised flood in Galloway, Scotland in April 2010. She drowned after falling into a swollen river.

In these, and many other extreme weather fatality cases, the victims came to the water, and not the other way around. Of course the water was behaving in unusual ways, breaking its banks and raising its levels, but still the decisions, actions and behaviours of many victims placed them actively and consciously in the hazard’s pathway. Risk-taking behaviour, the subjective perception of hazard magnitude, and cognitive biases which played out seconds before tragedy struck cannot be overlooked by our analysis. Therefore, in this chapter we will isolate and explore these behavioural cases, attempting to link them to theories and drivers which may explain the potency of active, risk-taking deaths throughout the fatalities database.

In a recent review of literature exploring the behaviour of people in and around floodwater, Becker and colleagues provided a comprehensive list of findings concerning floodwater fatalities in Australia, the United States, and Europe (Becker et al., 2015). Their conclusion identified the goal for emergency managers and the disaster reduction community of encouraging “appropriate behavior around floodwaters” (pp.327), the implication being that it was people’s decisions, choices and actions around floodwater which led to accidental deaths. Similarly to the findings of our database, flood death studies from the US, Europe and Australia report most deaths (70-90%) occurring in flood water, variously defined as inundated dry land, flooded roads and fords, swollen
watercourses or flooded ditches. The remainder are explained by secondary causes such as heart attack, fire, shock, electrocution and others, most of which fall beyond the scope of the current study. Consequently, both this study and its predecessors come to the conclusion that it is important to understand how the victims ended up in floodwater, whether they entered it voluntarily and why, all leading to an behavioural explanation of potentially avoidable risk taking.

Although the source articles rarely give us as comprehensive a profile of the casualty, as in the case of Michael Bartlett, there are almost always two things we know about the victims – their gender and their age. From many studies on natural hazard vulnerability, we know that age is an important contributing factor; the elderly and young children present greater levels of social vulnerability due to physical weakness and mobility constraints i.e. getting out of hazard’s way (Cutter et al., 2003). Gender is a category which according to the literature influences vulnerability in conflicting ways. Contextually, we know that in many regions and circumstances women are more vulnerable due to cultural factors and the fewer resources they command during the recovery phase (Blakie et al., 1994). The fact that risk discriminates is illustrated by multiple disasters in the developing world, where women are more vulnerable both directly and indirectly (Cannon, 2008a).

However, there is an alternative perspective on susceptibility, which derives from the cultural theory of risk perception. Mary Douglas and Aaron Wildavsky posited that individual perception of danger is reinforced by the particular world views of a societal group; feelings of safety are perpetuated by individuals, if the posited danger challenges their cultural norms (Douglas and Wildavsky, 1983). Building on this, behavioural risk perception research traced evidence of a “white male effect” (Funicance, 2000), which can be used to explain why men are more prone to accidental death as a result of socio-politically moulded risk behaviours. Societal norms of power perceptions (Boholm, 2003), political structures which favour men, and narratives of physical strengths and fearlessness cause men to take unnecessary risks more often than women, thus increasing the probability and consequences of accidental death and other adverse outcomes. Although risk perception is varyingly distributed across societal groups, studies have found that male gender and white ethnicity the greatest drivers of skew (Kalof et al., 2002; Slovic, 1999). The impact of identity-protective cognition drives the prevalence of risk scepticism in white males, as they cognitively dismiss signs of danger; not only does risk discriminate, but fear does too (Kahan et al., 2013). This
is one important explanation for the much higher rate of accidental death among men than women: in calculating avoidable deaths in the population, the Office for National Statistics measures the Standard Years of Life Lost (SYLL) per 100,000 population as a result of avoidable death through injury as between 1121.3 and 1293.8 for men between 2000 and 2013. The same figure for women is much lower, between 437.8 and 497.4 for the same period (Office for National Statistics, 2015).

Although the database of flood and extreme weather fatalities does not provide race data on casualties, as these are not typically reported in newspaper articles, gender and age data can be used to test the two types of vulnerability theory: contextual embodied vulnerability and cultural risk perception. The results presented in this chapter explore the gender and age distribution of the weather casualties to present a most likely profile of a flood and weather casualty in the UK. Underlying behavioural factors drive this trend.

**The aim of this chapter**

The chapter will use a number of age, gender, and context analyses to address the first two research questions:

- Who is dying from flooding and other weather hazards in the UK? What is the socio-demographic profile of a weather casualty?

- Are these the people we expect to be vulnerable? Do their social, economic, and physical characteristics predict them as vulnerable, according to the definitions and indices developed in disaster risk reduction theory?

By coding and totalling up demographic attributes of each casualty, and elucidating socio-economic characteristics where possible, the analysis will test the hypothesis that flood casualties in the UK follow a socio-demographic pattern of old age, reduced mobility, and feeble physical capacities, meaning that their contextual vulnerability predicts their fatal accident.

After testing this hypothesis, the chapter will turn to the final research question:

- Can definitions of vulnerability be applied to risk of death from weather hazards in the UK?
This question will be explored by identifying a range of alternative explanations for flood and extreme weather casualties, which are not linked to the contextual definitions of vulnerability.

The following sections will classify flood deaths by activity and situation, demonstrate that deaths outdoors are the most significant type of weather fatality, and cross reference these circumstances with gender and age distributions, which will prove that it is behavioural and active choices which make most of the fatalities avoidable.

### 7.1 Age of fatalities

Age is one of the factors that can be identified for most of the fatalities in the database; news reports most often report the age of the victim, even if the name is withheld. This allows tracing many patterns through the data, such as the location and activity of fatalities from different age groups. However, in the first instance, we will look exclusively at the age of the victims in an analysis isolated from other factors.

Table 7.1-1 Age of fatalities from the flood and extreme weather hazards 2000-2014: Most flood victims could be identified by their age, but about 14% of other hazard deaths were reported without this information. Percentages are given for the total of known age fatalities. For both datasets, the 40 to 59 age group reported the greatest number of casualties.

<table>
<thead>
<tr>
<th>Age</th>
<th>All Fatalities</th>
<th>Flood fatalities</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 19</td>
<td>38 20%</td>
<td>16 26%</td>
<td>0 - 19</td>
</tr>
<tr>
<td>20 - 39</td>
<td>46 24%</td>
<td>9 15%</td>
<td>20 - 39</td>
</tr>
<tr>
<td>40 - 59</td>
<td>61 32%</td>
<td>20 33%</td>
<td>40 - 59</td>
</tr>
<tr>
<td>60 - 79</td>
<td>41 21%</td>
<td>13 21%</td>
<td>60 - 79</td>
</tr>
<tr>
<td>80 - 100</td>
<td>7 4%</td>
<td>3 5%</td>
<td>80 - 100</td>
</tr>
<tr>
<td>unknown</td>
<td>32</td>
<td>1</td>
<td>unknown</td>
</tr>
</tbody>
</table>
Figure 7.1-1 Age distribution of a) all weather hazard and b) flood fatalities 2000 – 2014 in the context of UK population age distribution:
The pattern of age distribution for extreme weather events broadly follows the age distribution pattern of the population, with a slightly lower proportion of children and a spike in the 40-59 age bracket. Flood deaths also show this middle age peak and report lower proportions in the 20-39 age bracket. UK population data is for 2014 (Office of National Statistics, 2016).
Figure 7.1-2 Cumulative fatality age distributions and the cumulative age distribution of the UK population in 2014:
Fatalities for all hazards (light blue line) follow a similar curve to the cumulative population distribution (yellow background). Flood fatalities (dark blue line) have a much slower cumulative rate of increase.

Figure 7.1-3 Frequency distributions of the age of fatalities for all weather hazards:
The age of all hazard fatalities ranged from 2 to 91 years ($M = 42.33$, $SD = 21.297$). The age of the casualties has an almost normal distribution, with a slight positive skewness of 0.063 ($SE = 0.175$) and kurtosis of -0.914 ($SE = 0.348$)
The age of flood fatalities ranged from 5 to 91 years ($M = 42.85$, $SD = 23.23$). The age of the flood casualties has a close to normal distribution, with a slight positive skewness of 0.104 ($SE = 0.306$) and kurtosis of -1.085 ($SE = 0.604$).

Overall, in terms of population segments, the population of fatalities has a similar distribution to the overall population of the UK. This might suggest a general randomness in the age of the victims – with equal proportions in each age group suffering fatal flood and weather accidents. The size of the dataset calls into question the overall reliability of this data. The deaths with age unknown could skew the data significantly, if it was possible to distribute them. What can be visually perceived as an outlier on the graphs is represented by about 6-9 individual cases in all fatalities, and even fewer in the flood casualty dataset. Changing the age bins slightly exposes the sensitivity of the data. Therefore, only the strongest signals can be judged as worthy of further analysis. For example, by looking at deaths per million population in each age band (see Figure 7.1-5).

Mortality rates from floods and other weather hazards are very low in the context of other causes of death. The Office for National Statistics reports a mortality rate from preventable causes as 147.3 per 100,000 (ONS, 2015), so rates less than one are negligible at best and any conclusions drawn from them are associated with significance caveats. However, if we follow the suggested importance of the 60-79 and 40-59 age groups, we can surmise certain links of interest to this analysis.
Figure 7.1-5 Flood and all weather hazard average annual fatality rates per million population for the period 2000 — 2014:

ONS data on annual population in each age year was used, with an average population in each age year calculated for 2000 – 2014 (ONS, 2017). Fatalities with age unknown were proportionately distributed across the age bins. Fatality rates are very low and very sensitive due to the size of the dataset. Some interpolations can be made about the relative peaks and troughs for different age groups. For example, the spike in the 60-79 category can be expected from the literature, but the similar spike in middle age 40-59 is unexpected, and observed both for all hazards and for floods only. The dip in the 20-39 range for flood deaths may be an artefact of the data.

### 7.1.1 Looking at the age distribution of fatalities, which groups send interesting signals?

With the literature review having identified old age as a factor of vulnerability, it could have been assumed that the age distribution of victims would be skewed to the older age groups. The median age of flood and all hazard victims is 42, compared to the median age for the UK population of 40 (ONS, 2015). However, the small kurtosis of both casualty distributions suggests that the positive skew which makes the casualty datasets slightly older in the mean is driven by victims in the 40-59 age range, rather than the elderly group.
Therefore, as we explore the data further, it has to be recognised that the 60-79 age group is tangibly represented within the casualty dataset. This older population is important to analyse in terms of their relative mobility, frailty and activity at the time of death. In fact, looking at particular case studies, we can see that half of the casualties in this age group (22 out of 42 for all hazards) died whilst actively taking risks outdoors or attempting to help or rescue others. This will be discussed further in the next section.

However, the spike in mortality rates for the 40-59 group, and the clustering of the datasets around the median of 42, suggests a more interesting and less expected line of inquiry. This middle aged population is not a classically contextually vulnerable group. It is not specifically restricted by mobilities, entitlements, or knowledges. Therefore, the vulnerabilities of this group must be explored further in terms of their behaviour, choices and judgements that put them in situations of exposure to hazard. For example, a study on vehicle-related flood fatalities in Greece (Diakakis and Deligiannakis, 2013) reported the 40-69 population as the most vulnerable. If we look at the same cross section of the middle aged flood victims in the UK, 22 out of 87 died in vehicle-related accidents.

The proportion of children dying in weather events is slightly less than 0-19 year olds as a proportion of the population. Overall, there is little to suggest that this particular age group are disproportionately more likely to die in weather events. Also, we could speculate that reporting of children’s deaths is more precise and in depth due to the increased shock factor of such an impact, therefore, if any deaths are lost in the analysis, it is unlikely to be of victims under 19.

There are 38 casualties from all hazards aged 0 to 19, of whom 28 were aged 12 and over when they died. Risk taking behaviours are definitely traceable amongst this older group in the dataset; the attempts to watch torrents, experience, climb and swim recur in the stories of these casualties. Children and young people were swept away whilst watching waves and torrents, killed during outdoor sporting activities or whilst exploring river banks. Overall, two thirds of deaths can be classified as “active” i.e. not a result of falling debris or passenger death in a car accident. Amongst the 12 and older age group, this rises to 75%. The under-12s have died more often from impact accidents and blunt trauma – falling debris, vehicle accidents, etc. Many teenagers die outside and unsupervised.
Table 7.1-2 Extreme weather casualties 19 years old and under, 2000-2014: Older children and young people have died more frequently whilst engaging in outdoor activities and sports.

<table>
<thead>
<tr>
<th>Age</th>
<th>Number of casualties</th>
<th>Family accident</th>
<th>Active</th>
<th>Active %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 11</td>
<td>10</td>
<td>4</td>
<td>4</td>
<td>40%</td>
</tr>
<tr>
<td>12 to 19</td>
<td>28</td>
<td>5</td>
<td>21</td>
<td>75%</td>
</tr>
<tr>
<td>Total</td>
<td>38</td>
<td>9</td>
<td>25</td>
<td>66%</td>
</tr>
</tbody>
</table>

Linking risk-taking behaviour to age is a clear and supported analysis, which can be illustrated with this dataset. In fact, the under 20s die in much more expected ways than the over 70s, who present as many “active” accidents as they do “passive” fatalities.

A review of flood fatality studies by Becker and colleagues reports that the collective literature observes an overrepresentation of victims in the 10 to 29 age group; the vulnerable age group reported by the majority of studies (Becker et al., 2015). This differs from the findings of this study, which suggests that in the UK most victims have been of middle aged and elderly (40-69, 60-79) and when normalised by population it is the middle aged group, and in some cases the elderly which are overrepresented. Other studies have also reported increased vulnerability among the elderly: the over 70s in Australia (Fitzgerald et al., 2010); the over 60s for some studies in the United States (Ashley and Ashley, 2008).

When analysing other characteristics of the victims, there are three key findings which will need to be referenced to provide context to further analysis.

Firstly, the middle age range 40-59, which has not been explored in as much detail as the elderly or the young, may drive some of the more active, accidental and unpredictable deaths in the data.

For example, in late December 2013 two very similar flood fatalities occurred hours apart in Devon and Cumbria (Victim IDs 13.12.102 and 13.12.03). Both incidents involved men, one aged 46 and the other 48, both of whom had attempted to rescue their dogs from swollen rivers. The similarity of the two incidents, the victims’ decisions to walk outside in rural surroundings during hazardous weather, and their certainty of being able to swim in swollen torrents, all suggest that there are clear behavioural and gender factors driving the middle age spike of the dataset.
Secondly, it is clear that the elderly remain a population of concern for vulnerability analysis, but possibly not for the same reasons; the location, agency, and choices associated with the deaths of older adults in hazards needs to be examined closely. Whilst a 91-year-old pensioner did drown in her home near Neath Port Talbot in November 2012 (Victim ID 12.11.01), the database also describes two victims aged 84 and 86 (Victim IDs 11.07.01 and 08.12.02), who died in floodwaters outside their homes, one of whom had been driving and the other gardening. The first case is consistent with classic definitions of vulnerability; those that need the greatest level of protection as elderly, potentially with impaired mobility, and probably stationary in place. However, a large proportion of the victims who were elderly and vulnerable by age were mobile, active, and on the move, rejecting this definition.

Finally, children and young people also present with vulnerabilities, but for very different reasons depending on age – passive and accidental for the younger segment, active and risky for the older. Some under 10s drowned in cars and one prolific incident in 2014 involved a 7-year-old boy dying of CO poisoning from a flood pump (Victim ID 14.02.05). Conversely, 14 – 17 year-old victims are reported as swimming, walking, rescuing dogs, taking part in school trips and training courses, jumping in rivers and pools in hazardous conditions. These key age band contexts may present as compounding variables in the analysis of further vulnerability factors.

### 7.2 Gender distribution

Within the newspaper reports collected for this study, gender is the most ubiquitously reported characteristic of the victims. No gender was specified in only for eight cases out of a total 225 extreme weather casualties; here the victims were described as walkers, drivers or climbers, without any specific detail of name, age or other characteristics. A male or female gender was reported for all of the recorded flood victims.

Therefore, specific conclusions and compounding analyses can be drawn with this ubiquitous reported category variable. Previous research has reported a predominantly male population of victims across a range of flooded geographies and fatality contexts. Jonkman and Kelman (2005) confirm an overrepresentation of men amongst victims of fatal floods in the US and Europe. A 4:1 male to female flood fatality ratio has been reported in Australia for a very long period 1788 to 1996,
which has fallen to between 68% and 71% male for different sections of the more recent period 1950-2008 (Haynes et al., 2009; Fitzgerald et al., 2010).

The gender distribution of fatalities in the UK tells a very clear story. There is a significantly greater number of male victims compared to female victims. The type of hazard does not appear to alter this relationship: floods and all hazards having the same 70:30 male female fatality ratio.

![Figure 7.2-1 Gender distribution of fatalities from all weather hazards (outer ring, n=217) and floods (inner ring, n=62): Casualties of all hazards are predominantly male. This is a pattern which persists across all hazards types and age groups. Eight cases had to be omitted as the gender was not specified in the report.](image)

Table 7.2-1 Hazard fatalities gender distribution in the context of UK population gender distribution (ONS, 2015): Compared to the almost equal male-female distribution within the population, the fatalities database presents a very significant overrepresentation of the male segment of the population. *Eight of the case studies in all hazard fatalities did not report the victim’s gender.

<table>
<thead>
<tr>
<th>Gender</th>
<th>All Fatalities</th>
<th>Flood Fatalities</th>
<th>UK population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>153 (71%)</td>
<td>42 (68%)</td>
<td>31,793,600 (49.2%)</td>
</tr>
<tr>
<td>Female</td>
<td>64 (29%)</td>
<td>20 (32%)</td>
<td>32,803,100 (50.8%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>217*</td>
<td>62</td>
<td>64,596,800</td>
</tr>
</tbody>
</table>

Building on this distinction, we can analyse the geographical spread of flood fatalities by gender, as presented in Figure 7.2-2.
Figure 7.2-2 Gender and location of flood fatalities, 2000 – 2014:
Yellow squares represent female victims; orange triangles represent male victims. Males have been victims of flood death over a wider geographical area than females. Most females died in the west of Britain, where most of the fatalities occurred overall.
The very clear conclusion from the visualisation in Figure 7.2-2, is that all but four of the female fatalities occurred in the western regions: the skew of the geographical fatality distribution to the west has been discussed in Chapter 6. Women died predominantly in the fatality cluster areas; their deaths partially explained by the weather and activity factors which may explain the overall western skew. In contrast, the regional spread of male fatalities is much wider, occurring in almost all areas of the UK with a seemingly random pattern. Further analysis of the data in later sections will attempt to explain the gender characteristics of fatalities in terms of the optimism biases male victims may have employed during risky outdoor activities and driving decisions. The presence of both male and female deaths in the west of Britain suggests that the clustering is driven by weather patterns, topography, activities perused in these regions, and therefore geography explains many of the female fatalities. However, fewer male fatalities are explained by geography, and other factors, such as their activity at the time and their role in the hazard situation need to be considered.

7.2.1 Looking at the gender distribution of fatalities, what aspects warrant an analysis of compounding characteristics?

Many studies into the impact of flooding have presented the vulnerability of women as a key finding (Walker and Burningham, 2011b; Tapsell et al., 2002). In the aftermath of floods, women bear a greater proportion of the burden of mental health impacts, clean up and rebuilding tasks, and stress associated with temporary accommodation and looking after injured or displaced relatives. Inequalities inherent in social groups make women contextually vulnerable to the longer term and secondary impacts of floods and other weather hazards. In other regions, and especially in developing countries, women are at greater risk of death from flooding, often due to the cultural inequalities in the ability to swim (Cutter et al., 2003). The interaction of age and gender variables may make women more vulnerable to flooding due to the greater proportion of women amongst the contextually vulnerable 75+ age group (Walker and Burningham, 2011a). Furthermore, there have been studies which suggest that women are less likely than men to act in response to a flood warning, or to judge a warning as a mortal risk (Knocke and Kolivras, 2007; Fielding, 2007).

However, the results of this study contradict this position, with a clear and significant overrepresentation of men in the list of casualties. For the UK, and specifically for direct fatal impact, the data demonstrates a vulnerability other than contextual. Other studies, including Jonkman and
Kelman (2005), recognise that for this set of circumstances, male victims are the main feature of the results. The 70-30% male to female split of British victims is still lower than the 4:1 ratio reported by Coates (1999) for Australia.

The majority of the victims identified by the study were male and/or middle aged. Vulnerability theory has identified other groups – the elderly, potentially women in situations of inequality – as more susceptible. The victims do not seem to come from inherently vulnerable groups with contextual susceptibility due to a lack of capitals and therefore resilience. Although it was difficult to ascertain socio-economic information on many of the victims from the articles, several had skilled professions or trades, for example engineer, geologist, judge, joiner, lorry driver. Home and car ownership was implied in the majority of reports. The vast majority were UK citizens, bar one incident of migrant workers. It would be difficult to suggest that the victims were from marginalised or impoverished groups; in fact, there is more evidence to the contrary.

In general, the analysis of the gender distribution of flood and weather hazard fatalities, suggests two very clear directions for further analysis. Firstly, with a lot of the literature focusing on the contextual vulnerability of women, it is important to check how this maps onto the fatalities database: were the women who died vulnerable in other ways? Were they vulnerable as a consequence of culturally bounded activities? Or did their activity at the time of death roughly reflect the activity of their male counterparts, meaning only their frequency of death is lower? However, the main focus of further inquiry has to be the male victims, due to their significantly greater numbers. The compounding factors which drive their vulnerability and exposure, be they socio-economic, professional, or behavioural, warrant deeper exploration. The next sections will tease out indicators from the activity and location of these fatalities.

7.3 What were they up to?

The activity of the victim leading up to the accidental death in floodwaters and other extreme weather circumstances can uncover some of the reasons and motivations behind the hazard exposure. It can also suggest risk levels associated with different locations, activities, and proximities to the coast or water courses. This type of data is not always available within the newspaper reports. Often these qualitative characteristics need to be extrapolated from multiple
articles reporting the same death, and many assumptions have to be made. This tacit process and its caveats are described in more detail in the methodological discussion in Chapter 3. However, the richness of the news report material, and its superiority to strictly categorised demographic or coroner’s reports data cannot be underestimated. Reviewing dozens of case studies makes it possible to build a narrative landscape where multiple threads of context come to the forefront. Each case is individual and specific, but the interwoven circumstances draw attention to specific clusters of causes, some of which will be explored in the following two sections. However, as with age and gender, we will first attempt to look at categories of circumstance in isolation, starting with where the victims were when they were engaged in the activity which exposed them to harm.

Previous chapters have already stated that the majority of reported deaths occurred outdoors, and two thirds of them happened off the road i.e. not vehicle accidents. This leaves a very small number of deaths inside buildings, and even fewer deaths inside victims’ homes. The following section will look at each of these three broad locations in ascending order of magnitude – indoors, on the road, outdoors – to tease out the main types of activities and behaviour which may partly explain fatal outcomes.
Table 7.3-1 Location of fatalities from all hazards (storms, gales, blizzards and floods) and specifically flood fatalities: Very few people die in their homes or inside buildings during hazards in the UK. Road deaths represent only direct and extreme hazard impacts causing vehicle accidents i.e. collisions, low visibility, and aquaplaning fatal crashes are excluded. The outdoors, including urban areas and remote natural areas, are the most frequent location of flood and hazard fatalities.

<table>
<thead>
<tr>
<th>Year</th>
<th>All fatalities</th>
<th>Home/ Indoors</th>
<th>Outdoors</th>
<th>Road</th>
<th>Flood fatalities</th>
<th>Home/ Indoors</th>
<th>Outdoors</th>
<th>Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>13</td>
<td>0</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2002</td>
<td>27</td>
<td>0</td>
<td>12</td>
<td>15</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2003</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>10</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2005</td>
<td>15</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2006</td>
<td>8</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2007</td>
<td>41</td>
<td>2</td>
<td>34</td>
<td>5</td>
<td>14</td>
<td>2</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>2008</td>
<td>14</td>
<td>0</td>
<td>9</td>
<td>5</td>
<td>6</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2009</td>
<td>23</td>
<td>0</td>
<td>21</td>
<td>2</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>11</td>
<td>0</td>
<td>8</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>2011</td>
<td>12</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>2012</td>
<td>10</td>
<td>1</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2013</td>
<td>19</td>
<td>4</td>
<td>11</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2014</td>
<td>12</td>
<td>1</td>
<td>10</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>225</td>
<td>14</td>
<td>153</td>
<td>58</td>
<td>62</td>
<td>9</td>
<td>40</td>
<td>13</td>
</tr>
</tbody>
</table>

% of total: 6% 68% 26% 15% 65% 21%

### 7.3.1 Indoor fatalities

Between 2000 and 2014, fourteen people in the UK died inside buildings as a direct result of extreme weather events (excluding heat waves and cold spells, which are out of the scope of this study). This relatively small number includes only direct impacts, such as blunt trauma and asphyxiation from drowning or inhaling fumes. Of the fourteen casualties, nine can be attributed specifically to flooding, and five of these died inside their own home.

The people who died indoors ranged in age from seven to 91 ($M = 54$, $Mdn = 66$, $SD = 28.5$). The mean and median age are substantially higher than that for the entire fatality dataset ($M = 42$, $Mdn = 42$, $SD = 21$), confirming findings reported by previous studies. Jonkman and Kelman (2005) also contextualise older adult fatalities with their location: they report that most drownings inside buildings affect the over 60 population, which agrees with the finding that eight out of 14 indoor victims were over 60 years old.
Flood victims, indoors: Of the 14 indoor victims, nine died in flood hazards; five of these were in their own home; of these, one died of carbon monoxide poisoning due to a working flood pump, one was crushed by a flood induced landslide the others drowned when their house was flooded. These victims were exclusively elderly, and as far as the articles can tell us, the water probably breached their homes at night time, preventing their ability to prepare and evacuate. For some of the cases the homes were reported to be cottages and bungalows, suggesting ground level sleeping quarters, which made their residents particularly vulnerable. Of these five casualties, two pairs of victims died together, potentially while trying to help one another. The two indoor victims who were not in their own home at the time of death died of asphyxiation from flood pump fumes as they attempted to alleviate the impacts on their local rugby club. Their case will be discussed in more detail later in this chapter, together with other victims, who died whilst trying to help drain a cellar during a flood.

All hazard victims, indoors: Apart from flood victims, five other people died in their homes during gale force wind storms. Three of these homes are described as caravans, which may suggest additional contextual vulnerability of residents in temporary accommodation. Four incidents involved falling trees: two victims were crushed by a tree and two more died in a gas explosion caused by a falling tree. The final incident involved a caravan blowing over in a storm and its resident dying of blunt trauma. The age of these victims was more normally distributed, than the indoor flood victims, ranging from 16 to 81.

The male to female ratio of indoor victims 3:4, with six men and eight women dying inside buildings. This is a reverse situation to the significantly male dominated overall fatality population. Focusing on victims in their own homes leaves 1:2 male to female ratio. Given the older age of at home victims, this more even gender balance suggests that “at home” victims are broadly representative of the population, whereas the population of outdoor victims may be more significantly skewed by gendered behaviour choices. Overall more women than men died from weather hazards indoors and inside their own homes, although this difference was not significant within this very limited dataset.
7.3.1.1 Discussion – activities and other risk factors

People are not very vulnerable to fatal outcomes of hazards inside their homes. This may be a factor of the relatively low magnitude weather impacts experienced by the UK and the high quality of building construction; in more extreme geographies homes could be swept away together with their inhabitants. In a UK hazard context, property damage, loss of assets and valuables, loss of sentimental objects, mental health problems are much more likely to be the impacts experienced by people inside their homes at the time of hazard onset. Another contributing factor to the relative safety of the indoors could be the response of emergency services, which instigate ex ante evacuations before the hazard strikes. For example, 200 student homes were evacuated on the Aberystwyth seafront on the 6th January 2014, pre-empting a significant storm surge (article reference 201401.019); no casualties were reported after the event.

Outdoor fatalities dominate in both the flood fatalities and the all hazard fatalities dataset. Between the two datasets, flood fatalities have a higher share of indoor deaths. Referring to the fatalities database, we can see the variety of incidents which caused indoor deaths from floods.

Table 7.3.2 Indoor flood deaths 2000-2014: Two main themes emerge as compounding factors in indoor flood deaths – old age and the use of carbon monoxide emitting flood pumps.

<table>
<thead>
<tr>
<th>Victim ID</th>
<th>Age</th>
<th>Gender</th>
<th>Cause of Death</th>
<th>Indoor location</th>
<th>Activity at the time</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.02.05</td>
<td>7</td>
<td>M</td>
<td>CO poisoning from flood pump</td>
<td>own home</td>
<td>unknown</td>
</tr>
<tr>
<td>13.03.03</td>
<td>68</td>
<td>F</td>
<td>crushed when house collapsed in landslip caused by torrential rain and flooding</td>
<td>own home</td>
<td>sleeping</td>
</tr>
<tr>
<td>12.11.01</td>
<td>91</td>
<td>F</td>
<td>drowning when house flooded</td>
<td>own home</td>
<td>unknown</td>
</tr>
<tr>
<td>07.07.02</td>
<td>27</td>
<td>M</td>
<td>asphyxiation from pump fumes (or possibly electrocution), whilst attempting to remove water from local rugby club</td>
<td>local rugby club</td>
<td>rescuing</td>
</tr>
<tr>
<td>07.07.03</td>
<td>64</td>
<td>M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>05.01.08</td>
<td>79</td>
<td>F</td>
<td>two elderly women found dead in flooded home</td>
<td>own home</td>
<td>sleeping</td>
</tr>
<tr>
<td>05.01.09</td>
<td>85</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Looking at the victims, a few trends can be observed, albeit in a very small sample. Firstly, all but two of the indoor victims are over sixty years old, with several being very elderly, as well as one young child. Contextual vulnerability associated with old age and a lack of mobility can be a factor in these deaths, especially amongst the victims drowned in flooded homes. Additionally, two pairs of records in Table 7.3.2 represent multiple casualties at the same location; victims were overcome by floodwaters together, their susceptibility compounded by the circumstances of their partner –
although we do not have the details of the cases, it could be speculated that the tragic deaths may have involved the victims trying and failing to help one another to escape the floodwaters.

At the same time, one prominent case in this dataset is that of Chris and Bramwell Lane (Victim IDs 07.07.02 and 07.07.03) – a father and son from Tewkesbury who attempted to pump flood water out of the basement of their local rugby club and were overcome by the CO fumes during the summer floods of 2007. Their decision to help proved fatal, much like Michael Barnett's (Victim ID 07.06.03) attempt to clear the drain in Hull, the only difference being the indoor location of this incident. Therefore, even in this small sample of cases, which seem to adhere to classical understandings of vulnerability – the elderly and immobile overcome by the hazard in their home – the active individual taking an often calculated risk in an attempt to alleviate the impact of the hazard also becomes the victim.

Expanding the indoor fatalities list to all hazards maintains the pattern of circumstances: the additional five victims died in their homes as a result of falling trees during strong gales, three directly and two following a gas explosion caused by the falling tree. Regarding the more normal age distribution of these five victims, we might speculate that the less predictable and more sudden onset nature of a gale felled tree hazard in part drives the more representative age distribution of its victims.

The gender distribution, which shows several more women than men dying in their homes contrasts with the overall fatality dataset, but reflects the trends reported by previous studies on other home-centred impacts which affect women more than men, for example recovery and rebuild, loss of valuables, mental health impacts (Knocke and Kolivras, 2007; Fielding, 2007). With contextual models of women as traditional home makers, especially in older generations, we can see how this trend persists into the most severe hazard impacts. Alternatively, the at home victims are older, and the overall elderly population of the UK is female skewed, so this observation may simply reflect a representative distribution.

But without doubt, the main feature of indoor flood death is its infrequency. Considering the context of the 1953 Canvey Island flood, which killed 58 people in a single night, with an estimated 35 of these victims dying in their homes as the waters breached and collapsed buildings (Di Mauro and de Bruijn, 2012), indoor death for 2000-2014 are almost negligible. The key message of this part of
the dataset is that in the UK people inside their homes are well protected from the fatal consequences of flooding, and other weather hazards. Most accommodation is fit for purpose, resilient and reduces the risk of death and injury. Flood protection measures and infrastructure reduce the risk of a Canvey Island level breach to almost nothing. The UK is better protected in this case than other developed countries: as recently as 2010 a storm surge with an impact magnitude similarly destructive to Canvey Island hit the town of L’Aiguillon-sur-Mer on France’s Atlantic. In the wake of the storm surge, 47 people were killed, of which 42 were victims of drowning, and three quarters died in their single storey homes, which were inundated by flood water (Genovese and Przyluski, 2013). In the context of major European floods and storms, which kill people in their homes, the UK is well protected both by its comparatively milder weather events and by its commitment to flood protection, which enclosed many vulnerable communities during the late 20th century. As such, the low numbers are far from a “negative” result for the database, but a manifestation of successful disaster risk management.

The analysis of the few indoor victims which were identified by the database suggests three trends which may inform a subsequent analysis of compounding risk factors. Firstly, mobility and the ability to evacuate are a factor in assessing the risk to life posed by hazards. These are further exacerbated by the time of hazard onset and associated lack of knowledge and awareness i.e. more risk at night; and the speed of onset i.e. sudden felled trees are dangerous.

Secondly, as far as activities at the time of death are concerned, sleeping seems to be a risk factor in the context of ground level (for flooding) or poor quality and temporary (for gales) accommodation.

Finally, flood pump fumes are an important cause of indoor flood fatalities, although there were only three cases within the study period. They represent stories with the highest traction, mostly due to subsequent inquiry into the case. This is an important feature of the results, which resonates with findings (Hampson and Stock, 2006) in other countries in Europe and the US. Diesel generators are increasingly used after storms and other hazards lead to power cuts, and their fumes cause multiple deaths in the immediate three day aftermath period of a disaster (Iqbal et al., 2012). Despite regular warnings against indoor use, people continue to use pumps and generators, taking
risks and contributing to an annual European CO poisoning death rate of 2.2 people per 100,000 population (Waite et al., 2014), which is significantly higher than direct weather fatalities.

CO poisoning fatalities stem from the voluntary use of flood pumps in the absence of proper ventilation, against explicit warnings to the contrary. Besides the tragic death of the sleeping 7 year-old, this subset of fatalities suggests that indoor deaths also feature incidents of agency, risk perception bias, and behavioural choice. Looking at fatalities in other situations, we will see that there is a multitude of examples of people creating their own vulnerability and actively increasing their own exposure.

7.3.2 Fatalities in vehicles on the road

Direct hazard impact vehicle accidents, where people died inside their cars, account for 58 deaths between 2000 and 2014, which represents about 26% of all hazard deaths. Direct impacts exclude accidents arising due to multiple vehicle collision, reduced visibility, and aquaplaning accidents. They refer only to cases which are directly linked to an extreme weather impact, and cannot be entirely explained by driving ability, behaviour, inebriation or third party collisions. Aquaplaning and collisions accidents in inclement weather were also excluded from the scope of the analysis.

In the context of total road deaths, flood induced fatalities in vehicles are negligible. Although road deaths in the UK fell 45% between 2004 and 2014, annual deaths on the road were still 1775 in 2014 (Department of Transport, 2015). Even though this location represents a significant part of direct weather casualties, it is very low in the wider context of accidental and avoidable death in the UK.

Additionally, the reported 58 vehicle fatalities are a low estimate. Given the overall abundance of deaths on the road, even in severe weather conditions, these incidents are less unusual than other types of hazard fatality. The result of a significant news bias towards sensationalist items probably means that road traffic fatalities where flooding or other weather hazards play a role are vastly under reported.

Eight victims were passengers in the vehicle at the time of the accident, three of these were children. The other fifty are assumed to have been driving themselves, although this is not always clear from the reports. All but one of the incidents involved cars; one was a quad bike the driver of which fell
off into a flooded water course (Victim ID 10.04.01). All but two of the incidents involved people inside their vehicles; one incident involved a person trying to rescue their car in a snow storm (Victim ID 09.12.13), and another involved a toddler whose buggy was blown into traffic by a strong gale (Victim ID 13.03.01).

The gender of two road victims is unknown, but for the remaining 56, 63% are male and the remaining 37% are female: this almost precisely matches the overall gender distribution of the fatalities dataset.

The road victims ranged in age from three to 86 ($M = 49$, $Mdn = 51$, $SD = 20.9$). The mean and median age again somewhat higher than that for the entire fatality dataset ($M = 42$, $Mdn = 42$, $SD = 21$). This suggests that the slightly older population that died on the road is not driving the mean of the entire dataset.

In 21 cases of road fatalities we know the drivers’ profession. It is noteworthy that ten of these drove for a living, as lorry drivers, cab drivers, and other types of driving professions. We might speculate that, contrary to what we might intuitively think, skill is not a significant factor of risk reduction. However, this cannot be supported without knowledge of avoided fatalities by professional and unprofessional drivers.

Dividing road victims by the hazard which killed them, 13 died in floods, 39 in gale force wind, five during a storm by the coastline, and one in a snow storm. Looking at individual hazards, the snow storm victim died whilst trying to rescue his car which was stranded in the snow. The coastal storm victims were all members of the same family, evacuating their seafront property in two vehicles, when their cars were swept off the narrow lane by storm waves. The majority of vehicle-based gale fatalities (29 out of 39) were a result of wind felled trees, branches, debris or other objects crushing the victims’ cars either while driving or stopped. The remainder were mostly lorries overturned in high winds. For flood incidents, the majority (nine out of 13) of cases report people driving into flood water in the form of fords, bridges or standing water. The remaining four cases mention cars and drivers being swept away by swollen rivers, but do not specify how the vehicle ended up in the floodwater.
7.3.2.1 Discussion: motivations - travelling towards home or away from danger

The majority of flood fatality analyses from the United States report drivers as the predominant group of flood casualties, with up to 77% of casualties reported as vehicle related (Sharif et al., 2010; Ashley and Ashley, 2008). The proportion is lower in Europe, with only 27% of flood fatalities occurring during driving (Jonkman et al., 2002; Becker et al., 2015). This difference may in part be explained by a greater reliance on cars in the US, and greater commuting distances for many people, which can only be covered by driving. The current study of vehicle fatalities in the UK also acknowledges the importance of drivers and passengers amongst the casualty population; 13 for floods and 58 for all hazard types (21% and 26% respectively). Therefore, the study's findings are in line with those for Europe, but significantly below the number of driver victims reported for the United States.

To put this in context, we need to consider the vast difference in car dependency in the UK and the US. Transport surveys are undertaken annually (since 2010) in the UK and roughly every seven years in the US, 2017 and 2009 being the most recent releases. Although statistics are reported in different formats for the two countries, we can derive common values for comparison: annual private vehicle trips per person, and annual private vehicle miles per person. In the US in 2009 there were 3.02 daily vehicle trips per person, which represents 1,102 annual trips per person, which totalled 11,652 miles (U.S. Department of Transportation, 2011). In contrast, for the UK in 2010, 960 annual trips were taken and 7566 miles travelled per person, of which 64% and 79% respectively were by car (DfT, 2011). This means that in the UK in 2010 there were 614 annual trips and 5,977 annual miles per person by car — just over half of the US totals. The difference in distance for the average trip is just over a mile and a half (10%), so we can summarise that the US is twice as dependent on private vehicles as the UK.

Nevertheless, the volume of avoidable car deaths in extreme weather in the UK is significant and this begs questions about what motivates drivers to take risks in bad weather.

Looking specifically at flooding, we observe that most drivers choose to enter flood waters. With driving a major activity type at the time of death, it is important to analyse the motivations behind driving through floodwater or in perilous conditions. In the literature, many cases report the desire to maintain daily driving routines – work or family related drives (Becker et al., 2015). Driving
through floodwater with a view to reach a destination beyond it is a cause of death with a rising trend in Australia (15% in 1950-1979, 26% in 1980-2008) (Haynes et al., 2009; Zhong et al., 2013).

The UK flood fatality database confirms these motivations, with many driver and passenger death cases reporting people trying to reach home, crossing familiar fords or fields in unfamiliar conditions. One of the most widely reported flood casualties was 66 year old Mike Ellis – a retired school teacher from Shropshire, who left his car in a flooded field and attempted to get home on foot, crossing familiar territory. He had not anticipated the speed of the flowing water when crossing a familiar ford. Therefore, although many and potentially all flood drivers chose to enter deep water, it is likely that their motivation was to escape the flood, either by getting away altogether or by reaching their home, seen as a place of safety, or perhaps in need of rescue.

Importantly, multi-vehicle accidents, aquaplaning accidents and collisions in poor conditions were excluded from the scope of the analysis. Only vehicle inundation and direct flood accidents were considered. Certain studies report that the type of vehicle influences the likelihood of entering floodwater due to the driver's perception of risk: drivers of sports utility vehicles (SUV) and trucks are more likely to feel safe and drive through floodwater and as a result are reported to be more vulnerable to dying in a flood by studies from the United States (Becker et al., 2015). The current database did not record car types, and these were not often reported by the newspaper articles. However, this is an interesting line of inquiry when assessing victims’ risk perception and vulnerable populations at whom warnings and safety messages should be particularly targeted.

Extrapolating the analysis to all hazards, one important group of professionals who die during the performance of their jobs is lorry drivers, as well as other types of driving professionals, who died in storm and snow conditions on the road, usually as a consequence of strong winds (traffic accidents were out of scope for the study). Nine such cases were recorded by the database, all but one of the lorry drivers were male and their reported ages were between 39 and 55. It could be surmised that the confidence of the professional HGV driver in their ability to drive through extreme conditions causes an optimistic bias in their perception of the risk of floodwater.

Examining deaths inside vehicles from direct hazard impact as a whole, suggests three trends for further analysis and consideration. Firstly, it is interesting to explore how far familiarity with the geography and terrain influences the driving decisions of drivers during floods. The refrain of
“while crossing a familiar ford” persists in the newspaper reports throughout the study period and is followed by fatalities.

Secondly, the motivation behind driving in hazardous conditions, where it can be identified, seems to be two-fold and linked. Where a destination or nature of the journey is mentioned, victims who died in gale force winds are either driving normally in the course of their day or for their job. Victims who died in floods and storms are driving away from or through danger in order to reach safety, either actual – through evacuation, or perceived – by driving towards their home. However, this motivation may have put them at risk if they ignored road closures or warning signs to reach their homes nearby, where they had familiarity with the terrain. The power of this motivation, and the perception of safety within vehicles, has implications for police and emergency services response to drivers foregoing closures and diversions. A recent Environment Agency and AA survey of 14,000 drivers found that 68% say they would drive through flood water, rather than find a way around, despite explicit advice against it (Environment Agency, 2018).

Finally, the age and gender distributions of the road victims are much closer to those observed for the entire dataset, which suggests that the indoor deaths (described in 7.3.1) are more unusual in their presentation.

### 7.3.3 Outdoor victims – recreation and work at the time of hazard

Fatalities outdoors and off the road are the largest type of reported accident in the database, representing 68% of all deaths, and providing some of the most interesting results. 153 people died in this broad location, which is almost exactly twice as many as indoor (15) and road (58) fatalities put together. Flooding accounted for 40 outdoor victims, storms and gales killed 43 and 37 respectively, with a further 33 dying in extreme snowy and icy conditions. For floods, outdoor deaths represent two thirds of all victims, clearly making this a category for special focus in the analysis.

Amongst the outdoor fatalities for all hazards, 113 were men and 36 were women (gender was not reported in four cases). This represents a population which is 76% male and 24% female, a ratio of 3:1, somewhat higher than the 70-30% split observed for the entire fatalities dataset. The ratio transposes directly to outdoor flood fatalities with 31 men dying versus 9 women.
Age was reported for 136 outdoor fatalities, which ranged from two to 85 ($M = 40, \text{Mdn} = 40, SD = 20.3$). The mean and median age are slightly lower than that for the entire fatality dataset ($M = 42, \text{Mdn} = 42, SD = 21$), but actually equal to that of the UK population in 2014 (Office for National Statistics, 2016). Whist the indoor and road death age distributions has a slightly negative skewness (-0.5 and -0.4 respectively), the outdoor dataset is skewed positively from the mean at 0.2. The relative youth of this outdoor fatality population may be in part explained by the activities they were engaged in at the time of death.

Although activity at the time of accident is not always easy to tease out from the newspaper reports, certain assumptions can be made by following patterns narrative. In some cases, the reason victims were outside when they were fatally injured by a falling branch, or the purpose of their being in their garden in freezing temperatures, is unclear. But we can usually surmise from the context that people who were walking by the pier and were swept away were more likely to have been taking a recreational walk, than people who were hit by falling masonry in a town centre. Many reports often qualify the purpose of walking outside with a destination, if it was an errand or a job related walk. Where these descriptions are missing, often a recreational walk can be assumed. The mention of dogs, sports, scenery and taking photographs often classifies the walk as recreational. Based on these loose categories, 107 victims were undertaking some form of outdoor recreation, 10 were attempting to help alleviate the impact of the flood, or were trying to maintain their normal work pattern or daily errands i.e. were active but not recreational, 9 victims were in the process of escaping and getting out of the hazard’s way, and a further 27 remain unknown or unclassified.

In any case, the significant majority were engaging in recreational activities. For storm deaths, these involved different types of water sports, sailing and angling, as well as coastal walks and photography. For gale induced fatalities, the victims were dog walkers, hill walkers or urban tourists who were struck by felled trees, masonry, or other objects. In the extreme cold the recreational victims were hill and mountain climbers, caught in blizzards and avalanches, as well as poorly insulated party goers and other people who froze to death in sudden cold.

The outdoor victims of floods follow a slightly different pattern, where there are fewer unclassified, helpers and escapees are more precisely defined, and recreational activities at the time of death
completely dominate the dataset. The following parts of this chapter, therefore, will specifically focus on these 40 cases of outdoor flood fatalities.

Looking specifically at outdoor victims who perished in floods, three main types of activity can be identified, which cover 34 out of the 40 cases, with the remainder of cases not reporting a specific activity (see Figure 7.3-1).

7.3.3.1 Escaping
Two victims were overcome by flood waters whilst attempting to evacuate; both had abandoned their vehicles on flooded roads and were trying to escape on foot (Victim ID 12.06.01 and 07.06.05).

This was a tragic outcome of a desperate attempt to reach higher ground. The first victim had abandoned his car in a flooded field and attempted to cross a swollen stream, his case is described in more detail in Chapter 8; it could be speculated that awaiting rescue could have been the lower risk decision. However, it is unlikely that the second victim could have remained with his car as he was trapped under a railway bridge in rushing flood waters. Thinking back to the motivations of drivers to put themselves at risk, discussed above in section 7.3.2.1, the question of why the victim decided to drive into a low underpass in perilous weather is very difficult to answer. Both the victims were in known terrain, both were driving in the daytime, and as far as we know, both were aware of hazardous conditions. The circumstances of the deaths are difficult to judge as all reported
evidence was amassed ex post; at such a small sample size we can hardly draw conclusions about the decision-making process and risk perception of these victims.

7.3.3.2 Helping

Clearer patterns emerge amongst the six casualties attempting to help and alleviate the impacts of the flood. Five of the six victims were male, and only one was over 65, with the rest aged between 27 and 58. Their activities included clearing drains, trenches and culverts to allow flood water to drain, fixing water pumps, and preventing people from crossing vulnerable bridges. At least four of the five victims were acting in their professional capacity at the time as those responsible for the impacted infrastructure. Their risk decisions were driven by knowledge of the assets and a conscientious calculation. Extrapolated to all weather hazards, victims who died whilst helping include people who attempted to clear fallen trees or storm debris, and were crushed or electrocuted in the process.

In considering the helping and working activity category, it is important to mention that no emergency service professionals died in attempts to rescue victims at the time of hazard, besides Bill Barker — the police officer who died when the bridge he was guarding to prevent motorists from crossing collapsed into the swollen river in Workington, Cumbria in November 2009 (Victim ID 09.11.07). Other studies also report very low incidence of death amongst the professional and volunteer helpers and rescuers – about 6% in Australia (Haynes et al., 2009) and 1.2% across both the United States and Europe (Jonkman and Kelman, 2005). A low fatality outcome for a significantly high risk activity suggests two causal factors – the relatively low number of rescue attempts required in the context of overall low hazard risk levels, and the strength of risk-based professional conduct within the emergency services, which protect the lives of the personnel as well as of those in need of rescue. This risk conscious conduct might include: a) being better equipped to withstand the impact of the flood (including personal protective equipment and general levels of physical health); b) working in teams, whereas most victims in the database were isolated; and, c) having more skill in emergency response behaviour, having undergone specific training, and therefore being less likely to take fool-hardy risks. All other fatal rescue attempts in the current database were not from professional rescuers and their preceding circumstances can be categorised recreational.
7.3.3.3 **Recreational activities**

Overall, when considering the activity at the time of fatality, the highest proportion (65%) of fatal flood cases involving recreational activity is striking. Victims had made the decision to go outdoors in the first place in what were likely to have been very unfavourable weather conditions. This suggests a risk based choice or decision, which was followed through and ultimately miscalculated. We have no way of knowing whether these 26 people had access to local flood warnings, but the almost ubiquitous reference to poor weather in the newspaper reports suggests that they were not caught off guard by the conditions. The following section takes a closer look at the recreational risk takers.

In a review of relevant studies Becker et al. (2015) list recreational activity as the first category of activity undertaken by victims voluntarily entering floodwater. This is driven by a specific Australian phenomenon of enjoying floodwater based recreation, such as swimming, bathing or paddling, boating or surfing accounted for almost a 25% of flood related accidents between 1980 and 2008 (Haynes et al., 2009) and rose to 31% for a later review period 1997-2008 (Fitzgerald et al., 2010). This type of risk taking behaviour is not typical in the UK sample, potentially because deep long standing flood water is not a frequent impact of flooding, and more simply because it is likely to be too cold. However, the number of people undertaking other types of recreational activities around flooded watercourses is significantly high in the database at 26, which represents 65% of all outdoor flood casualties and 42% of all flood victims. Furthermore, at least six of these victims were undertaking water sports in the flood fatality sample and 10 in the storm fatality sample. Although much lower than Australia, these numbers are more in line with the scale of fatality from floodwater boating reported for the United States and Europe at less than 4% (Jonkman, 2005). None of the major flood fatality studies have explored more stereotypically British recreational activities, such as hill walking, hiking, dog walking (although pet rescue attempts have been studied), scenic walking; all of which feature dominantly in the present database. Highlighting the importance of these forms of recreation for flood fatalities and flood risk are novel contribution of this study.

Recreational activity contexts of flood death are present throughout the study period without an obvious trend, whereas in Australia it appears that recreational floodwater accidents are on the rise, from 5% for the period 1950-1979 to 25% of all flood fatalities between 1980 and 2008 (Becker et
Another interesting phenomenon explored by some of the most cited flood fatality studies (Jonkman, 2005; Ruin et al., 2009) is “flood tourism”, which draws vulnerable exposed groups of people to flooded areas or sights of rapidly flowing water. None of the entries in the database seem to reflect this activity, although evidence from the reports of the Somerset Levels floods of 2014 suggests that this type of recreational “flood tourism” also happens in the UK (BBC News, 2014). Thankfully, it did not lead to loss of life within the study period. However, there is evidence from the database of a similar “tourism” in a storm context when victims were swept away whilst taking photographs of waves during storms: a category represented by at least four cases.

Attempting to rescue pet dogs from swollen watercourses accounted for at least four fatalities in the database, with a further three cases occurring amongst dog walkers, who may or may not have been undertaking rescue attempts when they were overwhelmed by flood waters. This is particularly troubling, as several of the articles reporting these deaths mentioned that the dog escaped unharmed. The tragedy of these incidents is only made worse by their fallacy, wherein dogs are usually stronger and more resilient swimmers than humans. Although other flood fatality studies do not report specifically on dog rescue deaths, the category of saving pets, livestock or property as a precursor to drowning has been reported to be declining in Australia – from 25% of flood deaths in 1950-1970 to 3.5% in 1980-2008 (Becker et al., 2015). In contrast, dog rescue deaths appear in the UK flood fatalities database throughout the study period and prove to be a significant feature of the case studies.

With recreational outdoor activity the largest category of fatality circumstance, there is sufficient data and enough interest to warrant further temporal and seasonal analysis. As can be seen from Figure 7.3-2, deaths during recreational activities spike during the extreme events of June 2007 and November 2009.
Figure 7.3-2 Count of recreational activities at the time of outdoor flood deaths:
No obvious trend over time can be traced, although there are spikes in 2007 and 2009 when major flood events occurred. Overall, the peaks and valleys of the recreational fatalities follow the overall pattern of flood fatality, representing proportionate majorities each year. Walking seems to have been the most frequent activity at the time of accident. Recreational walking is the most common activity (dog walking without a specified rescue attempt is included in this category - three cases in 2008 and 2013).

Figure 7.3-3 Number of flood fatalities involved in recreational activity by month (blue) versus UK average (2000-14) monthly rainfall (green):
Monthly average rainfall taken from HadUKP (Hadley Centre, 2018). This visualisation suggests that there is a spike of recreationally associated flood deaths in the summer, especially in August, possibly driven by more free time during the holidays, and hence more time spent outdoors. However, the spikes around November and January, as well as the very small sample size (26 deaths) make it impossible to draw firm conclusions about seasonality. Comparing the pattern of monthly deaths to average monthly rainfall explains the January and November spike a little bit better – these can be associated with higher incidence of extreme convective events.
7.3.3.4 Discussion points

Looking at outdoor fatalities as a whole, with a specific focus on flood victims who died outdoors, three trends for further analysis come to the fore. Firstly, the male to female ratio for this location is much more starkly skewed towards male victims than it is in indoor and road fatalities. This is further true for recreational activities. The signal coming through the data is that middle aged men outdoors, likely engaging in recreational or helping activities die more often in weather hazards compared to other groups. Secondly, the data appears to show that recreational activity has a seasonal trend, and therefore potentially a mechanism for prevention and targeted warning can be based on seasonal risk profiles. These are two-fold: summer risks are driven by increased recreational activity, whilst January and November risks are fuelled by weather patterns. Finally, certain activities persist throughout the database and rarely but surely end in fatal accidents. These include dog walking, hill walking, beach photography, mountain climbing, attempting to help without proper training and equipment.

7.4 Compounding contextual and behavioural factors

The database created to identify extreme weather event casualties in the UK between 2000 and 2014 has suggested a number of interesting findings. Although instances of fatality are few, their contexts tell a variety of interesting stories, suggesting a broader epidemiology of flood and weather fatalities. What is clear from the above analyses is how partial and insufficient contextual vulnerability analysis is in explaining weather deaths for this dataset. Deprivation, age and mobility certainly play a role in predicting some vulnerability, but these factors are less significant than location (indoor/outdoor), activity choice (recreational), and even geography (Western skew). There is a strong argument for analysing the behaviours and risk decisions of victims, as well as their age, gender and location, in order to explain the causes behind loss of life.

What is further important, is how these factors interact. For example, Table 7.4-1 broadly groups victims into vulnerable (under 16, over 65, low mobility, social risk e.g. homelessness) and less vulnerable, and then analyses their activity as a voluntary risk (recreational activity, watching the weather, helping, choosing a path/ford, rescue attempt) or a passive state (low risk driving or walking, being at home, blunt trauma from falling debris).
The basic conclusion of this analysis, is that the overall distribution of the vulnerable and the risk averse in the dataset is similar. Roughly two thirds of the sample do not fall into an elderly or under 16 age group, whilst roughly two thirds took risks when they died. However, the intersection of these two sets indicates a more complex picture, in which 14% of vulnerably aged victims took a risk which resulted in their deaths.

Table 7.4-1 Comorbidity of vulnerability (age dependent) and risk taking behaviour (risk seeking activity) in weather hazard victims 2000-2014: Not all elderly people, or those aged 19 and under, perceive themselves as vulnerable and act in risk avoidant ways.

<table>
<thead>
<tr>
<th>Victim was of a vulnerable age?</th>
<th>Yes</th>
<th>No</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>% vulnerable</td>
<td>61</td>
<td>142</td>
<td>22</td>
</tr>
<tr>
<td>Victim took a risk?</td>
<td>141</td>
<td>46</td>
<td>38</td>
</tr>
<tr>
<td>% took a risk</td>
<td>63%</td>
<td>20%</td>
<td>17%</td>
</tr>
<tr>
<td>Vulnerable (by age) risk takers</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% vulnerable risk takers</td>
<td>14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other risk takers</td>
<td>101</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% other risk takers</td>
<td>45%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall, this angle of analysis suggests that behaviour and risk taking plays a significant role in explaining flood and other weather fatalities. Especially if the populations defined as vulnerable by the literature do not see themselves as such: the majority of elderly victims in the dataset were outdoors and active when they died: out of 35 people aged 65+, 15 were outdoors and 13 were driving. The impact of behaviour can also be traced in the number of cases (77 for all hazards, 18 for floods) where middle aged men died in the process of pursuing recreational and sporting activities in adverse conditions, often in familiar territory and with some expertise. There is a vast literature on the risk perception biases and heuristics prevalent to this demographic group, which can explain much of this behaviour, but rarely features in vulnerability assessment.

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6 For the purposes of this analysis, risk taking is defined as an active choice to pursue and activity in dangerous weather or flood conditions. “Risk takers” in the database were coded as those who took a risk, made a behavioural or emotional choice in treacherous weather conditions (sometimes it was not possible to derive from the report whether the victims were aware of the conditions or perceived them as hazardous). The limitations of this definition are discussed further at the end of this chapter.
Figure 7.4-1 Distribution of age by gender for fatalities from flooding and other weather hazards, split by location:

Crosses indicate means, and lines medians. The samples for victims who dies at home and on the road are quite limited and difficult to draw conclusions. The outdoor samples show the significantly greater number and age distribution of male fatalities. They also show that flood fatalities have a younger median range than other hazards, but overall all hazards and locations are particularly pronounced amongst fatalities in the middle age group.

Although we can trace certain compounding factors and comorbidities of vulnerability with the naked eye, it is worthwhile regressing the variables using statistical methods to note any dependencies which we might have missed. Doing this, however, necessitates repeating the caveats associated with the fatalities database: its very small size, especially in the context of UK mortality from other causes; the speculative nature of the majority of qualitative data categories – vulnerability, risk taking behaviour, recreational activity – which were assigned manually based on a consideration of the narrative text of the article; and the possible inaccuracies inherent in data harvested from newspaper reports.
Chapter 7

Risk and Behaviour

Table 7.4-2 Pearson correlation of multiple variables associated with extreme weather hazard fatalities: Variables considered include age and gender, hazard type (flood, storm, gale, blizzard as well as flood/not flood), activity at the time of the fatal accident (recreational or not), location of the fatality (indoor, road, outdoor as well as outdoor/not outdoor), vulnerability (classified by old or very young age and social factors), risk taking (classified by type of activity with inherent risks e.g. extreme sports).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Age</th>
<th>Gender</th>
<th>Hazard</th>
<th>Flood_NotFlooded</th>
<th>Recreational</th>
<th>Location</th>
<th>Outdoors_NotOutdoors</th>
<th>Vulnerable</th>
<th>RiskTaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age Pearson Correlation</td>
<td>1</td>
<td>.260**</td>
<td>.955**</td>
<td>-229*</td>
<td>-.075</td>
<td>.174</td>
<td>-.100</td>
<td>.335**</td>
<td>.139**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
<td>.863</td>
<td>.000</td>
<td>.000</td>
<td>.026</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
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<td>N</td>
<td>225</td>
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<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Gender Pearson Correlation</td>
<td>.280**</td>
<td>1</td>
<td>.131*</td>
<td>-118</td>
<td>-.010</td>
<td>.188</td>
<td>-.074</td>
<td>.179**</td>
<td>-.023</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.010</td>
<td>.049</td>
<td>.877</td>
<td>.886</td>
<td>.186</td>
<td>.266</td>
<td>.007</td>
<td>.735</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>225</td>
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<td>225</td>
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<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Hazard Pearson Correlation</td>
<td>.058</td>
<td>.131*</td>
<td>1</td>
<td>-.269*</td>
<td>.163*</td>
<td>.100</td>
<td>-.084</td>
<td>.903*</td>
<td>.156*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.383</td>
<td>.049</td>
<td>.000</td>
<td>.016</td>
<td>.137</td>
<td>.211</td>
<td>.165</td>
<td>.020</td>
<td></td>
</tr>
<tr>
<td>N</td>
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<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Flood_NotFlooded Pearson Correlation</td>
<td>-239*</td>
<td>-1.118</td>
<td>-260*</td>
<td>1</td>
<td>-.052</td>
<td>-.157*</td>
<td>-.046</td>
<td>-.263**</td>
<td>-.092</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.977</td>
<td>.000</td>
<td>.439</td>
<td>.019</td>
<td>.492</td>
<td>.002</td>
<td>.196</td>
<td></td>
</tr>
<tr>
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<td>225</td>
<td>225</td>
<td>225</td>
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</tr>
<tr>
<td>Recreational Pearson Correlation</td>
<td>-.075</td>
<td>-.010</td>
<td>.153*</td>
<td>-.052</td>
<td>1</td>
<td>-.153*</td>
<td>.280*</td>
<td>-.048*</td>
<td>.190**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.263</td>
<td>.888</td>
<td>.015</td>
<td>.439</td>
<td>.021</td>
<td>.000</td>
<td>.470</td>
<td>.004</td>
<td></td>
</tr>
<tr>
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<td>225</td>
<td>225</td>
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<td>225</td>
</tr>
<tr>
<td>Location Pearson Correlation</td>
<td>.174**</td>
<td>.108</td>
<td>.100</td>
<td>-.157*</td>
<td>-.153*</td>
<td>1.529**</td>
<td>-.241*</td>
<td>.385*</td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.019</td>
<td>.068</td>
<td>.137</td>
<td>.019</td>
<td>.021</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
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<td>225</td>
<td>225</td>
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</tr>
<tr>
<td>Outdoors_NotOutdoors Pearson Correlation</td>
<td>-.108</td>
<td>-.074</td>
<td>-.084</td>
<td>-.046</td>
<td>.280*</td>
<td>-.529**</td>
<td>1</td>
<td>-.191**</td>
<td>-.276*</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.107</td>
<td>.266</td>
<td>.211</td>
<td>.492</td>
<td>.000</td>
<td>.000</td>
<td>.004</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>Vulnerable Pearson Correlation</td>
<td>.338**</td>
<td>.119**</td>
<td>.093</td>
<td>-.203*</td>
<td>-.048</td>
<td>.241**</td>
<td>-.191**</td>
<td>1</td>
<td>.211**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.007</td>
<td>.165</td>
<td>.002</td>
<td>.470</td>
<td>.000</td>
<td>.004</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
<tr>
<td>RiskTaker Pearson Correlation</td>
<td>.139*</td>
<td>-.023</td>
<td>.155*</td>
<td>-.092</td>
<td>.196**</td>
<td>.365**</td>
<td>-.276**</td>
<td>.211**</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.037</td>
<td>.733</td>
<td>.020</td>
<td>.169</td>
<td>.054</td>
<td>.000</td>
<td>.000</td>
<td>.001</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
<td>225</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).
Many of the correlations in the table above are artefacts of the data, as several of the variables are derivatives of one another. For example, the categorical variable Location is compounded in the Outdoor variable, the strong correlation between Recreational and Outdoors variables is due to the fact that activity type, including recreational, was only classified for outdoor fatalities. The strong correlation between age and gender is also an artefact of the data. The strongest positive relationship is between age and vulnerability, \( r(225) = .838, p < 0.01 \), which is primarily explained by the fact that the vulnerability category was manually assigned by age, regardless of the victim's activity at the time and without considering indications of frailty or mobility, which were not reported in most cases.

Taking all of that into account, we can still perceive a few interesting relationships. When computing a Pearson correlation coefficient for a number of variables associated with weather casualties, age correlates negatively with hazards other than flood, \( r(225) = -.239, p < 0.01 \), and positively with location \( r(225) = .174, p < 0.01 \) (where 1 = indoors, 2 = outdoors, 3 = road). This suggests that the older a victim in this dataset, the more likely they are to have died in a storm, gale, or snow hazard, which is important in terms of illustrating aspects of contextual vulnerability. However, this pattern of older vulnerability is not statistically proven for flood hazards, where the victims during the study period were not overly skewed towards the older age groups.

Interestingly, gender (1 = male, 2 = female) correlates with vulnerability by age group (1 = over 18 or under 65, 2 = vulnerable age group) with a weak but positive relationship, \( r(225) = .179, p < 0.01 \), suggesting that the women in the dataset were more vulnerable. But due to the fact that the vulnerability label was assigned based primarily on age, this probably reflects the overrepresentation of women in the older age groups i.e. their contextual vulnerability. This is also explained by the overall majority of women in the older age groups in the UK population. From looking at the context of the fatalities, we know that men put themselves at risk and increase their exposure and vulnerability to hazard through behaviours and choices more often than the women in the dataset.

A new finding is the negative relationship between floods (1 = yes, 2 = no) and belonging to a vulnerable group: \( r(225) = -.203, p < 0.01 \). People from vulnerable age groups are correlated with type of hazard other than flood, even though the age analysis showed a skew for indoor flood
victims. This means that while floods killed more elderly people at home in the dataset, fatal flood risk did not discriminate by age overall.

Recreational activity does not correlate with anything but its own derivatives (outdoor and risk-taking variables), meaning that although it is the most common activity preceding a fatality, it doesn’t send a strong signal when compounded with other variables.

Vulnerability (1 = no, 2 = yes) and location (1 = indoors, 2 = outdoors, 3 = road) are positively correlated: \( r(225) = .241, p < 0.01 \), which is again unexpected, considering the elderly feature most in the vulnerable group and die indoors more than other age groups.

Computing the Pearson coefficient has strengthened some of the previous conclusions in the analysis, such as the relationship between age and other variables. Vulnerability correlates better with hazards other than flood, suggesting new perspectives on the age distribution of different hazard fatalities. While storms, gales, and blizzards seem to kill significantly more older people, there is no indication that the older you are the more likely you are to die in a flood. Unfortunately, no important relationships can be traced with recreational activities, although their prevalence at a time of hazard, especially among the middle aged and male populations is a significant finding of the study.

Importantly, the analysis of the fatalities database, and specifically flood fatalities, shows that the majority of incidents cannot be explained by either exposure (population density) or vulnerability (age skew) alone. Circumstances of death, as well as characteristics of the victim provide a much richer context for analysis. The main reason for this is that a significant proportion of the 225 extreme weather casualties can be explained by a combination of contextual vulnerability factors, behaviour, choices and perceptions of risk.

### 7.5 Discussion: dynamic vulnerability

Some of the results have identified victims who could easily be categorised as inherently vulnerable due to their age or impaired mobility. However, we have also seen multiple “invulnerable” victims, who came to harm because they made a choice which led them to be exposed to a hazard to an extent where their capacity to withstand impact was overcome by its intensity. These cases bring
the discussion back to the behavioural dimension of vulnerability, which has been overlooked by literature for some time (see Chapter 2). Most risk reduction efforts focus on populations vulnerable before the impact of a hazard, or whose vulnerability can be further increased after sustaining a hazard impact in a vicious feedback loop of contextual and outcome vulnerability. The fact that these types of people are not overwhelmingly represented in the fatalities database suggests that these efforts have been successful. The remainder of those who die is dominated by people whose vulnerability increased during the onset of the hazard; whilst being of good physical capacity and having the means of protection (house, car), these victims became vulnerable once they took a choice to increase their exposure through activity or location. This demonstrates that vulnerability is dynamic during the lifecycle of a hazard: whether or not we should consider an individual as vulnerable will depend not only on their inherent characteristics, but also on their potential behaviour in the face of danger.

7.5.1 Vulnerability by choice – hazard exposure through behaviour

The majority of the victims identified by the study were male and/or middle aged. Vulnerability theory has identified other groups – the elderly, potentially women in situations of inequality – as more susceptible. The victims do not seem to come from inherently vulnerable groups with contextual susceptibility due to a lack of capitals and therefore resilience. Although it was difficult to ascertain socio-economic information on many of the victims from the articles, many were skilled professionals, for example engineer, geologist, judge, joiner, lorry driver. Home and car ownership was implied in the majority of reports. The vast majority were UK citizens, bar one incident of migrant workers. It would be difficult to suggest that the victims were from marginalised or impoverished groups en masse; in fact, there is more evidence to the contrary.

It is likely that fewer contextually vulnerable individuals perish in floods because they are better protected by existing risk mitigation structures. With the focus on indices of deprivation, government targets protection measures towards vulnerable households. Indeed, contextually vulnerable residents are more likely to be integrated into regulatory structures, which have an organised and risk averse responses to hazard i.e. precautionary closure of schools, evacuation of care homes, frequent contact with the council, etc. Further, with the outdoors posing the greatest risk to life, it is logical that more elderly and less mobile populations are less likely to engage in risky outdoor
activities at a hazardous time. Although there are case studies to counter this, with one victim aged 58 dying in a quad biking accident in a swollen water course, as well as several elderly casualties during walking and dog walking. Of the 24 extreme weather casualties 70 years old and older, 11 were outdoors and eight were driving, demonstrating an active lifestyle and accidental death.

The dataset proves that the residual vulnerability to flood and weather death is not a social construction but a result of risk perception and behaviour. Optimistic biases (Weinstein, 1980) are clearly playing a part in middle-aged men enhancing their exposure to weather risks. Knowledge and experience, and its resulting confidence, plays a part in enacting these biases and causing men to take risks in hazardous conditions. This may be further driven by a “white male effect” (Finucane et al., 2000), which suggests that this segment of the population perceives much lower levels of risk than other demographic groups. Although no race data can be extracted from the newspaper records, it seems that many of the male victims do have a higher risk acceptance threshold, evident by the kinds of steps they take, which result in their fatal accident. Since the “white male effect” is driven partly by perceived beliefs about self-efficacy, it follows that middle age men “in the prime of life” might be particularly liable to over-estimating their capacity vis-à-vis flood waters. Whether it is hill walking and climbing in a storm, driving through surface water of inestimable depth, or attempting to clear a storm drain in a deluge, the male victims of the last decade have taken some significant risks which have claimed their lives. The majority of the victims identified by this study were not inherently at risk, but put themselves at risk through choices and behaviours.

Returning to the research questions, this significant middle-aged male contingent is not the contextually vulnerable population we would expect to be at risk from extreme weather. Disaster risk reduction methodologies, informed by vulnerability theory, cannot be applied to mitigate the risk posed to those who put themselves in harm’s way during UK weather hazards. This is a population currently out of scope for protection and mitigation activities. Whether they can be reached by current warning dissemination strategies and how they respond to these warnings is a matter of interest and concern.
7.5.2 Weather awareness outdoors and on the road

Linked to the analysis of indoor/outdoor deaths are the findings examining the activities which casualties were engaged in when they suffered their fatal weather event accident. With the majority of fatalities happening outside the home, victims were mostly active: making choices, taking measures and routes, responding to the weather hazard actively. In the case of high winds, occasional deaths from blunt trauma can be considered passive i.e. falling debris. However, for most of the fatal incidents, victims consciously selected their activity and were able to influence their location.

It is interesting to explore the reason people are outdoors and exposed to harm. In the case of the driving victims, the destination of their journey may have influenced their risk taking behaviour and decisions to drive through water (Cave et al., 2009). One tragic example in 2005 saw a family of five perish in stormy coastal waters whilst driving a narrow flooded lane to escape their isolated home. Could an earlier evacuation have saved them? Alternatively, would they have been safer staying in their home, even if it sustained storm damage? Did their desperation to reach safety make them more vulnerable to high-risk decisions? In multiple other cases, we encounter victims driving home in flood conditions and getting into trouble in the water, crossing familiar fords that have become swollen, or driving through surface water of inestimable depth. Most of these journeys were taking the victims home, to flood-struck areas, and they may have been aware of the flood warnings. Some were tourists in unfamiliar territory, but at least five of the 14 flood deaths on the road were people driving on everyday errands, attempting to maintain normal patterns while the flood waters were high. This might point towards an attenuation of risk through familiarity, wherein knowledge bias might reduce the perceived risk of a local flood.

A study of evacuation behaviours (Bañgate et al., 2017) has suggested that the need for proximity of loved ones, and conversely the panic response generated by their distance, drives people to move towards their families and evacuate as a unit during a crisis. This social attachment need can influence a driver’s decision-making and cause them to take greater risks in attempting to reach home. Similarly, familiarity with local terrain can generate an optimism bias, encouraging drivers to take risks with familiar geographical features in unfamiliar weather circumstances.
Overall, we see drivers who were aware of some risks and made calculated trade-off decisions between perilous driving conditions and errands (shopping, doctors’ appointments, etc.). On the one hand, we have a resilience argument which suggests low vulnerability and high adaptive capacity on behalf of these individuals. It would be impossible to estimate, how many similar basic journeys were taken safely in comparison to the five casualties. Near-misses and rescued motorists were out of scope for this study, but featured in the database as false positives. The low level of incidents overall suggests that for the majority of these drives the risk trade-offs are paying off.

On a case-by-case basis, there were at least three tragedies which occurred when drivers followed satnav directions. Nine articles reported that victims drove through water of inestimable depth; there is photographic evidence to show that there are cases when drivers disregard road closures and warning signs. These cases, illustrating a wider risk taking environment, suggest a number of clear policy activities aimed at their avoidance. Some measures which could avoid flood casualties on the road include integrating wet weather conditions driving skills and flood water warnings into driving instruction; radio warning dissemination reminding people not to drive through deep water, building warning messages into mobile satnav systems.

7.5.3 Resilient recreation with fatal outcomes

The list of activities and behaviours in which the victims engaged is very counter intuitive for an ex post disaster risk analysis. People engaged in recreational outdoor activities during weather hazards, often with warnings in place. In the case of flood deaths, these are predominantly victims who fall into swollen watercourses as rivers rise, or while they remain high. These deaths are mostly in rural areas. Walkers’ and pedestrian deaths in urban areas are almost exclusively reported to have happened at night, and although this cannot be verified, alcohol is anecdotally reported as a potential factor i.e. walking home from the pub or a party.

For daytime rural recreational walkers, precursors to flood conditions include heavy rain and localised flooding, probably visible and accessible to the victims through weather observations and local warnings. Yet we find that they still choose to go out into the perilous environment.

“They checked the weather conditions before they set off, but they were both very experienced climbers and sensible lads so we had no reason to worry.”

- Victim ID 09.02.05 and 09.02.06, 2006, article reference 200902.214
Amongst climbing deaths, the reporting often suggests that the climbers were experienced and aware of the conditions; relying on their expertise in challenging circumstances was a calculated risk.

*Friends hoped the popular climber’s experience of survival techniques would have saved him when he went missing on Wednesday. But he stood no chance in the howling winds and harsh conditions on the Wester Ross hills.*

- Victim ID 08.02.01, 2008, article reference 200802.101

The five sailors, canoeists and kayakers reported drowned during flood conditions are all reported as experienced in their sport.

*Police in Devon named an experienced canoeist and instructor who died after being pulled from the River Dart as Chris Wheeler.*

- Victim ID 09.11.03, 2009, article reference 200911.067

Once in this environment, we observe through the stories that further risks are taken – selecting slippery paths, wading fords, standing on bridges and banks, attempting to rescue swimming dogs.

Factors influencing the decisions of walkers, dog owners, climbers and sportsmen include their experience. Whilst a low level of experience could indicate a higher likelihood of placing oneself in a situation of risk through lack of knowledge, it could at the same time ensure safety as a less experienced person may be more cautious about undertaking the activity in hazardous weather. The optimistic bias of local knowledge and activity experience may cause seasoned enthusiasts to put themselves in greater danger, even if their experience makes them more resilient to the consequences of this danger (see Figure 7.5-1).
A positive bias based on experience can cause people to unwittingly increase their exposure to hazard, thus amplifying their level of risk.

7.5.4 When warnings work

Another interesting aspect is the response of victims to warnings and observed weather. Were the walkers aware of the dangerous conditions? Why did they choose not to heed warnings? These questions can be informed by the severity level of the weather warning at each casualty’s location. Provided they were aware of warnings before setting out, what level of warning would they have heeded, if the active one was ignored? Although interesting, such an analysis can be little more than speculative, as it would be impossible to assess whether individual victims had encountered warnings and chose to ignore them, or simply did not check for warnings.

However, an interesting case study for this phenomenon is the St Jude’s storm of 2013. The study identified six victims of the storm, and their indoor/outdoor split was equal\(^7\), unlike the general trend towards outdoor fatalities. Two of the deaths were outdoor recreational. However, the magnitude of the storm could have predicted a far higher death toll. There were multiple severe warnings in

\(^7\) Three deaths occurred indoors, but two within the same household. The remaining two casualties were road and outdoor recreational respectively.
place and a lot of media attention communicating the severity of the event. The low level of
fatalities could be a result of a high number of avoided deaths through heeded warnings.

**Table 7.5-1: Casualties during St Jude's storm, October 2013**: It could be assumed that fewer
fatalities would have resulted in a higher death toll.

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Victim ID</th>
<th>Age</th>
<th>Gender</th>
<th>Cause of death</th>
<th>Activity at the time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Oct</td>
<td>13.10.01</td>
<td>46</td>
<td>M</td>
<td>gas explosion caused by falling tree in St Jude storm</td>
<td>unknown</td>
<td>Hounslow, London</td>
</tr>
<tr>
<td>2013</td>
<td>Oct</td>
<td>13.10.02</td>
<td>34</td>
<td>M</td>
<td>gas explosion caused by falling tree in St Jude storm</td>
<td>unknown</td>
<td>Hounslow, London</td>
</tr>
<tr>
<td>2013</td>
<td>Oct</td>
<td>13.10.03</td>
<td>16</td>
<td>F</td>
<td>crushed by tree fall on caravan in St Jude storm</td>
<td>Sleeping</td>
<td>Hever, Kent</td>
</tr>
<tr>
<td>2013</td>
<td>Oct</td>
<td>13.10.04</td>
<td>51</td>
<td>M</td>
<td>crushed by tree fall on car in St Jude storm</td>
<td>Driving, watching storm</td>
<td>Harrow, London-Newhaven, East Sussex</td>
</tr>
<tr>
<td>2013</td>
<td>Oct</td>
<td>13.10.05</td>
<td>14</td>
<td>M</td>
<td>swept out to sea during St Jude storm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

However, the casualty described as “watching the storm” (victim ID 13.10.05) is an illustration of a
common relationship with weather as something to be observed, rather than acted upon - a benign
force of nature that happens on a screen or somewhere overseas and does not pose direct mortal
danger. It would be fascinating to explore the relationship between the framing of weather events
in the media and their mortality rates. Does sensationalising a “super storm” make it safer? Does
“experiential” reporting – dramatic images of journalists blown away by gales - encourage the public
to take risks on the coast? Additionally, there is a strong literature on warning fatigue, or failure to
act upon warnings when their frequency is high, but the hazard impact is low. Wachinger et al.
(2013) cite the example of the 2011 Tōhoku earthquake and tsunami, which was preceded by a
smaller event in 2010. Without many living memory tsunami experiences, the perception of the
2011 warning was downgraded by recipients to the impact level of the 2010 event. Few actions
were taken on behalf of the exposed population, and the impacts of the hazard were extreme as a
result of unrealistic warning perception.

### 7.5.4.1 Heroes at risk

Several cases are described where people died whilst attempting to help their loved ones,
colleagues and communities. Blocked storm drains have claimed at least four lives in the period
2000-2014 as people tried to clear them in attempts to alleviate the flood. One tragic case in 2007
graphically describes the victim’s (ID 07.06.03) slow death in the torrent as his foot is stuck in the
storm drain, which he attempted to clear to protect his place of work from the flood waters. As this story repeats throughout the period, a clear action point becomes the improved maintenance of storm drains, specifically in culverts and cul-de-sacs, and potentially their replacement with finer mesh grates to prevent people getting stuck.

Table 7.5-2 Victims who died whilst trying to clear debris to help their communities in extreme weather conditions: Better drain maintenance and design may have prevented some of these deaths. However, the case studies also demonstrate risk taking behaviour and an assumption of expertise.

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Victim ID</th>
<th>Age</th>
<th>Gender</th>
<th>Cause of death</th>
<th>Activity at the time</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>Feb</td>
<td>14.02.03</td>
<td>71</td>
<td>M</td>
<td>electrocuted by fallen power lines</td>
<td>clearing fallen trees with chainsaw</td>
<td>Bremhill, Wiltshire</td>
</tr>
<tr>
<td>2011</td>
<td>Jul</td>
<td>11.07.02</td>
<td>68</td>
<td>M</td>
<td>drowned</td>
<td>trying to unblock a culvert</td>
<td>Inverness</td>
</tr>
<tr>
<td>2007</td>
<td>Jun</td>
<td>07.06.03</td>
<td>28</td>
<td>M</td>
<td>died of hypothermia whilst trapped in a flooded drain, which he was trying to clear. Rescuers were on the scene for 4 hours. The storm drain had been a makeshift grid put in place after earlier flooding, branches had blocked the drain.</td>
<td>trying to unblock neighbours drain during heavy rain and flooding</td>
<td>Hessle, Hull</td>
</tr>
<tr>
<td>2003</td>
<td>Jan</td>
<td>03.01.05</td>
<td>58</td>
<td>M</td>
<td>found unconscious in manhole, asphyxiation? Drowning? Injury?</td>
<td>trying to unblock neighbours drain during heavy rain and flooding</td>
<td>Chingford, London</td>
</tr>
</tbody>
</table>

Other cases report people rebuilding fences, moving livestock, checking on neighbours and clearing fallen trees in response to the flood. Again, biases and trade-offs clearly featured in the behavioural decisions made by these people; we know for certain that they were aware of the conditions, seeing as they were directly attempting to alleviate them. However, one common theme is the improper handling of equipment; specifically flood pumps. Deaths in subterranean cellars and rooms from carbon monoxide poisoning due to improper ventilation is an infrequent but persistent cause of death. Similarly, electrocution from large pieces of equipment, like chain saws for clearing trees, can also be noted as a repeated cause of death. Tracing such patterns among the “hero casualties” may suggest communication and training needs in the use of large, often hired or loaned, equipment.
Advice from emergency services, and their improved availability during hazard recovery and alleviation, would also prevent untrained people from attempting to perform emergency response tasks unsafely.

### 7.5.5 Risk perception

Most authors describing cases and contexts of flood fatalities agree that risk perception is one of the main factors explaining the behaviour of victims in and around floodwater, which led to avoidable fatal accidents (Jonkman and Kelman, 2005; Ruin et al., 2009; Diakakis and Deligiannakis, 2013; Franklin et al., 2014; Drobot et al., 2007). Studies of flood behaviour which used survey responses to understand perceptions and motivations, specifically of motorists driving through floodwaters; respondents usually talk about considering situations safe, judging floodwater to be standing and shallow, assessing risk to their life as low (Ruin et al., 2007).

Underestimation of risk may stem from a cognitive bias, specifically a normalcy bias (Omer and Alon, 1994) which refuses to recognise a hazard as impacting the status quo conditions; hence drivers will follow familiar routes despite warnings, in the knowledge that their familiarity with the terrain will make them safer. Proof of this may be identified in the fact that studies have reported the majority of automobile fatalities during floods happening within five miles of a driver’s home (Maples and Tiefenbacher, 2009); drivers in familiar terrain could be more likely to choose risky driving behaviour due to their familiarity with the environment.

Other types of cognitive biases have been observed amongst people living in frequently flooded regions, where there was awareness of flood impact and consequence, but an heuristic bias which led victims to reject that their own lives and property were at risk (Burningham et al., 2008).

Other kinds of bias may have also impacted the behavioural strategies of flood victims; Frank McKenna (1993) presented a range of bias models which people at risk apply when making behavioural choices. Unrealistic optimism and the illusion of control are two such strategies, wherein people who feel confident and in good health perceive warnings as not applicable to them, but targeted towards weaker and more contextually vulnerable people, therefore they choose to ignore warnings and proceed with risky behaviours – for example taking a recreational walk on the pier in a severe storm. In this model, it follows that younger adults are more vulnerable because they on the whole have fewer health problems, and therefore do not perceive themselves as
vulnerable and targeted by warnings. McKenna further claimed that in the context of chance and an active warning, people feel themselves to be more in control over environmental events than they actually are. This is a compounding factor on the already unrealistic level of optimism about a dangerous weather event. It follows that the group most susceptible to unrealistic optimism, and associated risk taking, are those in society who are the better adjusted; a conclusion which reflects the population age and gender distribution of weather hazard fatalities quite neatly.

Arguably the most notable theorist of optimism bias is Neil D. Weinstein, who wrote extensively about its cognitive model in the 1980s and beyond. Weinstein condensed different types of hazard events to five characteristics which make them susceptible to be perceived in an optimistically biased way i.e. characteristic of the hazard in the perception of the victim, not characteristics of vulnerability or resilience which are intrinsic to the victim themselves (Weinstein, 1980). To map the Weinstein model onto weather hazards, strong optimism bias is likely when an individual has no personal experience of the hazard, the hazard occurrence is low probability, it is seen as on the whole controllable and expected to present with early warning signs (Weinstein, 1989).

In the context of the present study, it hard to judge the level of hazard experience in the database population. Anecdotally, there are some indications that as many of the victims were local and familiar with the terrain, they may have had previous experience of a similar hazard event, if the area is in general high risk. From this perspective the database casualties do not fit Weistein’s model for optimism bias. However, for all impacts besides storm-felled trees, the other optimism bias criteria are met. Very extreme events of high magnitude, footprint and duration are relatively rare in the UK, and when they do occur they do so with sufficient warning, and the degree of infrastructure and organisational structure around flood defence and prevention makes these events in particular appear controllable. In fact, one of the reasons the relatively safe Somerset Levels floods of 2014 gained so much traction was the perceived lack of control and inability to immediately solve the impacts. Hence, we can say, that on the whole many of the extreme casualty inducing events from the fatalities database fit Weinstein’s model and could have been perceived with a significant degree of optimism bias and an illusion of control by its victims. The degree of optimism bias does not reflect the degree of hazard severity, and a confident perception of one’s superior resilience may lead to significant risk taking.
Having established this, there remains a question of what can be done about it, and whether anything needs to be done at these negligible, and mostly avoidable, risks of death. Could the practice of risk communication and the science of perception inform the process of fatality avoidance? Primarily this could be approached through the dissemination, targeting and amplification of specific warnings.

We know that people process risk information using mental models. Models vary from person to person depending on a number of factors, but inherent characteristics and previously experienced risks. If a risk is considered acceptable no action is taken to protect oneself or others, but if it is considered unacceptable there is potential for preventative and mitigating action. This potential can be increased by amplifying the perception of the risk and lowering the threshold for acceptability in order to influence the mental model (Svenson, 1988).

Deaths from weather hazards could be partially avoided (some random accidents will always claim lives, the rate cannot be reduced to zero) by understanding weather warnings, their attenuation and potency.

### 7.6 Conclusion: risks and behaviours

This chapter considered the people who died in floods and other weather hazards in the UK from 2000 to 2014. It analysed some of their ubiquitously reported characteristics, concluding that the majority of victims are middle aged and/or male. This contradicted with some previous findings, but echoed others. Importantly, it answered the second research question:

- Are UK flood and extreme weather casualties representative of the people we expect to be vulnerable? Do their social, economic, and physical characteristics predict them as vulnerable, according to the definitions and indices developed in disaster risk reduction theory?

Contrary to vulnerability literature, the analysis has concluded that the profile of the extreme weather casualty in the UK is not the classically vulnerable with contextual characteristics of reduced capacity to withstand hazard, rejecting the hypothesis that flood casualties in the UK
follow a socio-demographic pattern of old age, reduced mobility, and feeble physical capacities.

Beyond this analysis, it becomes apparent that mortality is driven by behaviour, and choice of location, not classic vulnerability theories of poverty, old age and female gender. Activity at the time of death, risk perception which encourages the pursuit of the activity, and the often recreational, rural and exposed nature of this activity are the main drivers of hazard casualties. The intersection between recreational activity near, rather than in, bodies of water, which lead to flood death is a previously unexplored category and this study’s main contribution to the literature. Hill walkers, hikers, climbers and dog walkers who perish in swollen watercourses are not always reflected by flood fatality figures, although they ought to be.

Therefore, the final research question can be partially answered:

- Can definitions of vulnerability be applied to risk of death from weather hazards in the UK?

The analysis shows that whilst the definition is partially true, and old age predicts some of the vulnerability to death from flooding, mostly a different paradigm is needed for the UK. The results highlight that the choice of activity, as well as the choice to pursue it in dangerous weather conditions is a significant driver of weather casualties, explaining some, if not all, of the deaths. Importantly, as we know from previous chapters, mortality also cannot entirely be explained by either exposure (population density) or vulnerability (age). However, there is a westward skew in the geography of hazard death.

Returning to the research questions, the outdoor casualties do not fall into the expected vulnerable population definitions due to the mobile and recreational nature of their activities. By focusing warnings on people in their homes, many indoor deaths are prevented through protection and evacuation measures. However, people, putting themselves at risk through choices and behaviours, being outdoors in hazardous conditions, or having a lack of awareness of their hazardous surroundings are harder to reach and protect.
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It’s a dreary Thursday morning in late June, and it’s begun to rain heavily. You live in a quiet village, which sees flooding from time to time. There have been a few flood and weather warnings out over the last few days, and several remain in place today across the region, the majority are low risk – Environment Agency Flood Alerts and Yellow severe weather warnings from the MetOffice. Maybe you check them, probably you don’t – your house is not low lying or maybe you have plenty of sandbags in the garage, or maybe there just hasn’t been anything that alarming in the news. You’re used to this sort of weather in these parts, have been for decades – you’ve lived in and around this area most of your life, ten years in this house. The rain only started up about an hour ago; it probably won’t be too bad. You’ve booked some blood tests at the surgery in the neighbouring village; it would be a headache to miss them and have to reschedule. And you’re always told how last minute cancellations strain the service. Besides, if enough people are deterred by the weather, you’ll get seen quickly and make it back before the situation deteriorates. It’s less than a mile to drive. Overall, there seem to be very few reasons not to go.

So you head out, make your appointment and start to drive back. It’s been raining heavily for about two hours now. You can see the runoff building as it rushes down the lane. This will flood for sure, but you’ll be back in time; it’s only a short distance and you know the roads well.

About half a mile from home your way is blocked. The nearby brook has burst its banks already and the water in the lane looks too deep to drive through; you are well aware of the dangers of driving through deep water. So you leave the car by some farm buildings and head out on foot. It’s only half a mile to your house, and you know this terrain like the back of your hand. In fact, if you cross this field you’ll be able to get over the brook in a shallow spot further upstream. The torrent won’t be so strong there, surely.

You make it about 100 yards to the crossing place, the water is rising rapidly and the torrent sweeps you off your feet. You struggle to get up, even though the water is not deep here it is fast. It is, however, fast. The current overcomes you in minutes.

…
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It is impossible to know whether Mike Ellis, a 66-year-old retired schoolteacher from Bitterly near Ludlow, Shropshire, was in fact certain of his route through the fields on the 28th June 2012. But we know he headed away from his car and towards the flood, rather than head back and seek help. Eye witnesses saw him dragged under the current from a safe distance (article reference 201206.030-53).

Flood and weather warnings were in place that day. The highest level of anticipated flood risk was yellow (only the first rung of severity on the scale), from the Flood Guidance Statement, issued by the Flood Forecasting Centre to Category 1 and 2 emergency responders. The National Severe Weather Warning Service (NSWWS) from the MetOffice issued three yellow (likelihood = 2 out of 4, impact severity = 3 out of 4) warnings for heavy rain in the afternoon, gale force winds, and the potential for localised surface water flooding across England and Scotland, with Shropshire specified as one of many affected counties. A similar level of warning had been in place the previous day in Scotland, and the plume of warm moist air had moved southwards, bringing the possibility of 15-30mm rainfall in a space of 3-6 hours.

But even if Mike Ellis saw these warnings, they did little to change his resolve to head out that day for a non-emergency appointment. Perhaps it was their precautionary yellow level, or perhaps, as risk perception theory teaches us (Weinstein, 1980), the optimistic bias of his local knowledge and flood experience caused him to disregard the alert. In any case, the warnings in place were unsuccessful in preventing a flood casualty that day.

The purpose of flood and extreme weather warnings is to improve resilience and increase safety for people and property (Environment Agency, 2015). However, some authors have suggested that warning systems in different countries often struggle to strike a balance between warning specificity and effectiveness (Parker et al., 2009). There are few examples of specific national level surface water flood warning systems; most are catch-all style systems for several types of hazardous weather over a large regional footprint. It is difficult to provide a specific surface water flood warning in practice, although specific localised systems, warning householders directly, have been implemented in the UK by the Environment Agency, including in The Tysoes in Warwickshire, in Catcliffe near Rotherham, and in parts of Lancashire (Wigan, Croston) (Parker et al., 2011). The rest of the UK public are informed through an opt-in system of warnings from the Environment
Agency for river and coastal flooding, which are managed differently in England, Scotland, Wales, and Northern Ireland. For some regions of England and in Wales, these alerts took the form of Twitter alerts (push notifications) in 2013 – the first warning system of this kind in Europe (HM Government, 2016).

A range of meteorological, hydrological, catchment, and flood defence status data comprises the Flood Guidance Statements issued daily at 10:30 AM by the Flood Forecasting Centre to emergency responders in potentially affected counties. These warnings are then disseminated along media channels, but their visibility to affected users is also not certain. There are also NSWWS warnings, which usually take the form of a heavy rainfall alert with an impact and likelihood parameter. Sometimes, the text of the alert specifies surface water flooding, but its reach is also limited by those individuals which seek it out, and the strength of its media signal, i.e. how much it gets picked by media channels, is in itself is subject to factors like the severity and footprint of the event and the news context of the day.

Elsewhere in countries with developed disaster management systems, the situation is remarkably similar, as the team from the Flood Hazard Research Centre and the National Flood Resilience Review summarise (Parker et al., 2011; HM Government, 2016). In the US, the National Weather Service issues combined weather and flood warnings, which some specific flood details. Australia provides centralised flood warnings, but local governments are responsible for forecasts of flash floods, where lead times are less than six hours. Notably, Australia also runs the national Emergency Alert system, which notifies people within the risk area on their mobile phone. France has separate local and city-level warning systems from 22 regional forecasting centres, such as the Marseille flood alert system, and publicly available alert platforms, which are also there for users to proactively find (Demeritt et al., 2014). The pan-European Meteoalarm system provides heavy rainfall warnings, which can sometimes suggest flood impacts, but overall most issuing authorities refrain from quantifying and forecasting surface water flooding, and even flash flooding.

The core rationale of any early warning service is to protect and enable individuals and emergency responders to prepare for and protect against an oncoming hazard. The protection of lives and livelihoods are the primary purpose of the Environment Agency’s, MetOffice, and FFC warning
systems. Substantial investments, and frequent revisions, have been made to these systems over the years.

**The aim of this chapter**

The chapter attempts to address the final research question:

- Can definitions of vulnerability be applied to risk of death from weather hazards in the UK?

It looks at the question from a different angle, by analysing situations identified by weather and flood warning systems, which are seen to induce states of vulnerability, and whether these match casualties i.e. accidents in vulnerability contexts. This analysis will provide an alternative angle for looking at vulnerability to flood death in the UK by analysing the success of a particular tool which mitigates it.

This chapter will test the hypothesis that **warnings are effective at protecting lives**, by investigating whether a lack of, or a specific level of warning is predictive of a casualty.

### 8.1 Methodology

Warnings data was obtained from the MetOffice and the FFC. The format of useable data differed widely across the two datasets, and between them, because of frequent updates to warning protocols and formats. Therefore, no comparative analysis was possible, and the warning datasets were explored individually.

#### 8.1.1 MetOffice National Severe Weather Warning Service dataset

Until 2011, NSWWS had evolved over several iterations based on a system approach developed after the poorly forecast storm of October 1987, which killed 18 people and caused substantial damage. It was followed by a strategic review of the weather warning service, which established the need for early warnings of hazardous weather, which would be monitored and followed up by flash warnings, once the certainty of the event became clearer (Hunt, 1989). For extreme rainfall, and associated surface water flooding, a Tier 1 event triggering the NSWWS is one where more than 15mm of rainfall is expected in three hours or less. The NSWWS Nimbus system issued
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Advisory, Early, and Flash warnings to emergency responders, and disseminated them to the public via internet and media channels. Advisory warnings refer to events with a five day lead time or less at a confidence level of 20-60%; Early warnings are for events with the potential for severe disruptive impact across a large region, with a likelihood of over 60%; Flash warnings report on severe weather events at an 80% likelihood within up to two hours before impact (HM Government, 2016).

The Nimbus warnings obtained from the MetOffice came in a range of formats, including .txt and .xml and their content format changed three times between 2006 and 2011. Mostly, the warnings in three categories (advisory, early, and flash) reported the expected event (rain, snow, wind), a list of affected regions with a percentage likelihood parameter, commentary on the possible nature of the event and a timeframe for the actuality of the warning. However, the format of presentation, the level of detail in the free text commentary, and the file format was highly inconsistent over the time period needed for this study.

Since April 2011, NSWWS warnings have adopted a consistent impact based alert format, which for the sake of brevity this chapter will refer to as “SWIFT” (Severe Weather Information Forecasting Tool). This type of alert comprises a description of the meteorological casual conditions, a map of the affected region, a description of the likely impacts, a qualification of the risk level based on likelihood and impact severity, a time frame for the warning effect, and a list of affected local authorities (Demeritt, 2012). The level of risk is communicated using a two parameter matrix – likelihood and impact severity. In the disambiguation (Met Office, 2018), risk to life is referred to in the red and amber quadrants, with likelihood being the main factor of difference between these risk assessments. An example of the .pdf format warning document is presented in Figure 8.1-1.

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8 For the purposes of this chapter, we will use the acronym SWIFT (Strategic Weather Information Forecasting Tool) to refer to this new impact based warning system, as this is the naming convention in the warning archive obtained from the MetOffice, even though the acronym had been used by the Met Office to describe its forecasting systems before the implementation of the impact based convention.
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Figure 8.1-1 Example of a MetOffice NSWWS impact based alert format from April 2011: The standard alert format contains a meteorological forecast, and an impact forecast. A risk assessment matrix qualifies the event on a scale of likelihood and impact severity, with yellow quadrants representing low level impacts, amber quadrants representing disruptive impacts, and the red section warning against dangerous weather which poses risks to life (Met Office, 2018).

A key feature of the warning is the four by four risk matrix, like the one reproduced in Figure 8.1-2, upon which the level of each warning is based: red alerts only represent events which have the highest possible likelihood and the greatest measurable destructive potential. Amber warnings represent events which are judged as three or four on both the impact and likelihood parameter. To trigger a yellow warning, an event has to measure above two on either parameter, but not on both. Impacts are assessed based on several vulnerable categories, including risk to life, property, infrastructure, utilities, etc. In terms of risk to life, the MetOffice commentary on the risk matrix

The Met Office have issued a Yellow Warning of Rain
Issued from 06:00 on Thu, 28th Jun 2012 and 22:00 on Thu, 28th Jun 2012

After heavy rain impacts in southern Scotland overnight, further areas of thundery rain will move south across northern England and Scotland during Thursday. The rain is forecast to become heavy and persistent during the afternoon and evening across southern and eastern Scotland, while at the same time moderate to heavy showers are expected to develop across the north Midlands and northern England. The public should be aware that excellent flooding may occur.

For more details please go to: http://www.metoffice.gov.uk/weather/forecast/update.html
Issued by the Met Office at 12:54 on Mon, 25th Jun 2012
Updated by the Met Office at 17:04 on Thu, 28th Jun 2012
recognises that risk to life is a potential impact in the amber and red warning quadrants i.e. at impact severity assessments of three or four (Met Office, 2018).

Figure 8.1-2 Reproduction of a NSWWS risk matrix post March 2011:
Yellow warnings are more common because they are linked to events where only one risk parameter must be significant (x > 2). Red warnings are reserved for the most severe events that are forecast with the greatest certainty.

An entire warnings archive from 2006 was provided by the MetOffice to assist with this study. Formats, naming conventions and archiving had inconsistencies throughout that dataset. The start of the full archive is effectively 2008, as only warnings from Scotland were available for 2006, and 2007 warnings were from November and December only. 2008, 2009, and 2010 provided fairly consistent warning formats and volumes. Another difficulty associated with this part of the archive is that flash warnings were provided in both .txt and .xml formats. The majority of these files were paired by their time stamp, effectively creating duplicates of one another. However, occasionally, they were standalone warning documents in only one format. The total number represents the number of warning files, the number in brackets is an estimate of the number of individual warnings (roughly half). 2011 was a transition year between the warning systems, which saw the Advisory, Flash, and Early warning Nimbus system replaced with the SWIFT impact based risk matrix format warning, described above in Figure 8.1-2. This transition happened around March, and so warning formats vary across the months, with the legacy system still in place for most of that year. A further 253 .xml warning files from 2011 could not be classified into any of the described categories, and are probably duplicates of one of the sets. The new system also issues .txt warnings and alerts, with the latter having slightly longer lead times, and therefore matching more closely to the Early
warnings which preceded them. The various Met Office weather warning datasets available for analysis is summarised in Table 8.1-1.

**Table 8.1-1 Warning data obtained from the Met Office:** The warnings archive presented inconsistencies in the way data was classified and arranged. * Represents half of the total number of files, as most assumed to be duplicated in .xml and .txt formats.

<table>
<thead>
<tr>
<th>Year</th>
<th>System</th>
<th>Early</th>
<th>Flash</th>
<th>Advisory</th>
<th>Impact based</th>
<th>Alert</th>
<th>Warning</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>Nimbus</td>
<td>9</td>
<td>84</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>pdf</td>
</tr>
<tr>
<td>2007</td>
<td>Nimbus</td>
<td>5</td>
<td>87</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td>txt, xml, pdf</td>
</tr>
<tr>
<td>2008</td>
<td>Nimbus</td>
<td>95</td>
<td>1381</td>
<td>(691*)</td>
<td>20</td>
<td></td>
<td></td>
<td>txt, xml</td>
</tr>
<tr>
<td>2009</td>
<td>Nimbus</td>
<td>96</td>
<td>1791</td>
<td>(896*)</td>
<td>417</td>
<td></td>
<td></td>
<td>txt, xml</td>
</tr>
<tr>
<td>2010</td>
<td>Nimbus</td>
<td>73</td>
<td>1436</td>
<td>(718*)</td>
<td>0</td>
<td></td>
<td></td>
<td>txt, xml</td>
</tr>
<tr>
<td>2011</td>
<td>Nimbus/SWIFT</td>
<td>8</td>
<td>331</td>
<td>168</td>
<td>557</td>
<td>45</td>
<td>237</td>
<td>txt, xml, pdf</td>
</tr>
<tr>
<td>2012</td>
<td>SWIFT</td>
<td></td>
<td></td>
<td></td>
<td>752</td>
<td>12</td>
<td>79</td>
<td>pdf, txt</td>
</tr>
<tr>
<td>2013</td>
<td>SWIFT</td>
<td></td>
<td></td>
<td></td>
<td>673</td>
<td>3</td>
<td>49</td>
<td>pdf, txt</td>
</tr>
<tr>
<td>2014</td>
<td>SWIFT</td>
<td></td>
<td></td>
<td></td>
<td>624</td>
<td>29</td>
<td>69</td>
<td>pdf, txt</td>
</tr>
</tbody>
</table>

Considering the warnings archive in the context of the fatalities dataset, the two could be matched by three parameters: event type, region, and date. In order to extract the necessary data from the .xml warning files, a custom-built parser was used for the early part of the archive. As 2006 and 2007 warning datasets were incomplete, the NSWWS Nimbus warning analysis focused on the time period January 2008 – March 2011, which reports 19 flood deaths and a further 41 other extreme weather casualties that were date matched against any warnings in the Nimbus warnings dataset.

For the latter part of the archive, warning information needed to be extracted from .pdf files which were mostly consistent in their format, but varied in the amount of content provided by each section. For example, a meteorological description could vary from three to ten lines or more. To process these documents, Docparser by Dausinger Digital EURL - an online parsing service platform - was used. More than two and a half thousand warning documents were securely uploaded to the parser, nine distinct parsing rules were designed to extract data based on its location, format, word count, and other features. The parsing rules were mostly designed on a text Variable Position rule basis, which instructed the parser to match specific ubiquitous text phrases, e.g. “Valid from”, in the
warning text and extract a set number of characters or words before or after the text anchor. Using this format, rules were generated to extract warning date\(^9\), time valid from, warning level, hazard, impact description and list of affected areas. The results were downloaded as an .xls file wherein each record represented a single .pdf warning. After the analysis, the warnings and outputs stored in the system were securely deleted. This provided a dataset of more than two thousand warnings for the time period April 2011 to December 2014, during which there were a further 15 flood deaths and 34 casualties from other severe weather events.

The parsed data was cleaned and filtered in an Excel workbook. A pivot table was designed to split and count warnings for individual regions, hazards, and severity levels. It would be senseless to link a flood casualty in Devon to an amber warning in Cumbria; therefore, the intersection of affected regions and fatalities was carefully checked. Finally, the cleaned regional datasets were matched with the flood fatalities dataset by date, using -2 day sensitivity window, to account for delays in reporting of the fatality, as discussed in Chapter 5.1. Given flood event lag times, and the possibility for late or compilation reporting, the analysis involved checking for warnings present on the day of the report, the day before the report (Date-1) as most casualties are reported to have died “yesterday”, and two days prior to the report (Date-2) to account for events with longer lag times, or incidents when waters remain high after their initial warning and warnings which remain actual later than 23:59 on the day of issue (this is often the case for advisory and early warnings). The results analyse the presence, level, and regional precision of a warning in place when the fatality occurred.

8.1.2 Flood Forecasting Centre Flood Guidance Statement calendar

The Flood Forecasting Centre issues Flood Guidance Statements (FGS) daily at 10:30 AM for the exclusive use of Category 1 (emergency services, local authorities, NHS bodies) and Category 2 (co-operating bodies, responsible for action in their own sector e.g. transport and utilities companies) responders, as classified by the Civil Contingencies Act 2004. The FGS combines NSWWS and Environment Agency Flood warning data into a forecast of general flood risk, interpreted for actionable risk assessment decision by its recipients (Flood Forecasting Centre, 9 For parsing date information, separate rules for the day, month, and year had to be written because the warning date format did not match any conventional date formats, e.g. June 27\(^{th}\) 2014, the “th” could not be recognised by the automated parser as part of a date string. Separate date elements were extracted and recombined in standard dd/mm/yyyy format using Excel’s =DATE function.
National and local level information is accumulated by forecasting teams in the Environment Agency and Natural Resources Wales, which covers all types of flood events, considers the status of catchments and flood defence assets, and builds up into a comprehensive understanding of flood risk. Expert assessments, consultations, and local information augment the level of detail for the assessment (Flood Forecasting Centre, 2017). Each FGS provides a five day forecast, and the daily edition is updated with live information.

For the purposes of this analysis, the FGS calendar was used. The calendar is an ex-post tool, which was provided by the FFC for the purposes of this study. It shows the highest level of risk for any county for a five day period represented as the colour of each individual day. For example, if a yellow risk level was forecast for the 28th of June 2011 in one region or more, the calendar will report it as yellow, even if no warnings were issued anywhere else in the country. This makes the FGS calendar a good indication of any flood risk forecast across England and Wales, although it does not allow to trace the country level warning back to its regional source. This, however, can be compensated by aligning it with a NSWWS warning of the same date, as this is one of the sources for the daily FGS.

Importantly, the FGS calendar was provided for the period 2011-2014, which means it can be used to build a longer analysis time period, picking up where the NSWWS Nimbus .xml warnings end and stretching to the end of the fatality dataset. At the same time, it augments and reflects the NSWWS SWIFT warning dataset for the latter part of the archive. Whereas NSWWS impact based warnings do not always specify surface flooding events as an impact of severe rainfall alert, this information can be reinterpreted and built upon by an FGS.

Warning level data was extracted from the FGS calendar, pivoted, and formatted in excel. It was then matched with the flood fatalities dataset for the period 2011-2014 to display the maximum country level flood risk forecast for each day of death, with a -2 day sensitivity to account for delayed reporting or standing flood water.

Having the three warning datasets together, spanning the period 2008 – 2014, there were two possible paths for the analysis. Basing the inquiry in the fatalities dataset, it was feasible to explore the warning context of each casualty across both platforms – NSWWS and FGS. This approach could have shown whether the individual could have potentially been exposed to a warning (in the
case of a disseminated NSWWS alert), and/or whether an institutional protective response was in effect at the time of the casualty (in the case of an amber or above FGS). This inquiry could tell whether everything possible had been done by disaster impact reduction systems and bodies, and whether the casualty was therefore an accidental and inevitable result of individual decision making. However, given the opt-in nature of flood warning systems in the UK, this case-by-case approach would invite significant uncertainty into the analysis, considering that even if the warning was disseminated, there would be no way to tell whether the casualty had seen it and chosen not to heed it, or whether the casualty had in fact been unaware of the advised risk level. Hence, besides providing an interesting policy outcome context to individual case studies, this approach would yield little useful information.

Instead, the following section presents the results of a time series analysis, similar to that undertaken for rainfall intensity and death in Chapter 5. By taking a longitudinal view, we can assess the potential effectiveness of severe weather warnings by tracing their relationship to the frequency of fatal incidents. We attempt to show whether the absence, or indeed existence of a warning, at a particular level of forecast risk, is predictive of a casualty, by considering the entire set of warnings and their intersection with dates of death. To augment this analysis, we also look at whether individual cases of fatality were preceded by particular levels of warning.

### 8.1.3 How the results are analysed

The assessment and verification of extreme weather warnings for the evaluation of their effectiveness has a widely applied practice in the UK, US, Australia, and other countries with advanced warning systems. These analyses look for the ratio between forecast and observed events, to evaluate the rate of correctly predicted hazards (Doswell et al., 1990). The US NOAA defines a number of key measurement parameters for this type of verification and proposes their analysis using a 2x2 contingency table.
Table 8.1-2 NOAA contingency table from the Glossary of Forecast Verification Metrics: This standard 2x2 contingency table approach is used in forecasting practice to assess the effectiveness of warning systems. Reproduced from (NOAA, n.d.).

<table>
<thead>
<tr>
<th>Event forecast</th>
<th>Event observed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>Hits</td>
<td>False alarms</td>
</tr>
<tr>
<td>NO</td>
<td>Misses</td>
<td>Correct negatives</td>
</tr>
</tbody>
</table>

Within this type of matrix, any warning system would seek to maximise the number of forecasts which are “hits” or “correct negatives”, and drive down the number of “misses” and “false alarms”. To establish the effectiveness rate of the system using the output of the contingency table, the NOAA verification glossary suggests several metrics, including the Probability of False Detection (POFD), or the False Alarm Rate, which is calculated by dividing the number of false alarms by the total number of observed events. The closer the rate is to 0, the more accurate the forecast system. Conversely, there is the metric of the Probability of Detection (POD), which is derived from the number of hits divided by the total number of events forecast. The closer the rate is to 1, the more accurate the system.

This approach was used to assess the effectiveness of the MetOffice Extreme Rainfall Alert (ERA) pilot in 2009 (Hurford et al., 2012). For four case study regions, the study counted 10 observed flood events when an ERA was issued (hits), 23 flood events when no ERA was issued (misses), and 19 ERAs when no flood was observed (false alarms), and the correct negatives could not be counted. This suggests that the ERA pilot had a False Alarm Rate of $19/(10+19) = 0.655$. The analysis did not present a no forecast/no observed event measure for the calculation of a POD.

The analysis of the warnings datasets will attempt to generate POD and False Alarm Rate values where possible to evaluate the effectiveness of warning systems in forecasting deadly events. However, this method should be taken with the caveat that a False Alarm Rate for fatality is not an indicator of warnings issued unnecessarily, because whilst no death corresponded with the warning, other severe impacts may well have occurred. Furthermore, the existence of a warning when no fatality occurred may well be an indication of the positive application of that warning, which worked to keep people safe on a particular occasion.
Therefore, as well as using standard verification measures of forecast effectiveness, analysis of warnings and fatalities will also follow a similar logic to that used in Chapter 5 when comparing the intersection of extreme rain events and fatalities. Essentially, we are investigating whether a warning was in place at the time of death. However, we are also interested in the risk level of each warning and what the implications of its “hit” or “miss” may have been.

**Table 8.1-3 Analysis matrix for warnings and fatality data:** Double ticks represent predictive events, where warnings at various levels and flood fatalities coincide. A tick and a cross represent protective warnings: where a warning was in place and no one died. A cross and a tick represent missed casualties: where a fatality occurred when no warning was issued. Double crosses represent low risk events where there was no warning and no fatality.

<table>
<thead>
<tr>
<th>Warning: yellow</th>
<th>Fatality</th>
<th>No Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>accurate/predictive</td>
<td>protective</td>
</tr>
<tr>
<td>Warning: amber</td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>predictive</td>
<td>Protective</td>
</tr>
<tr>
<td>Warning: red</td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>predictive</td>
<td>Protective</td>
</tr>
<tr>
<td>No warning: green</td>
<td>X✔</td>
<td>XX</td>
</tr>
<tr>
<td></td>
<td>failed</td>
<td>Accurate</td>
</tr>
</tbody>
</table>

One important distinction to note here is that the different warning systems have slightly different traffic light interpretations. FGS warnings alert of individual risk to life for vulnerable people or those in unfamiliar circumstances e.g. crossing fords, at the yellow level of impact severity (Flood Forecasting Centre, 2017), while NSWWS SWIFT warnings (2011 — 2014) acknowledge risk to life only at amber and red level impacts (Met Office, 2018). Pre-2011 NSWWS Nimbus warnings do not have a colour coded impact severity assessment scale, but report hazard magnitude as heavy/severe or very heavy/very severe.

Using this analysis matrix, we can count the total number of events in each quadrant and draw conclusions about the proportion of predictive, protective, failed, and accurate warnings. Double tick events, amber and above for later NSWWS, are predictive: the alert warned against risk to life, and a life was lost. Ticks and crosses, amber and above for NSWWS, can be seen as protective: the alert warned against risk to life and all lives were safe, hence we can assume that the emergency systems mobilised succeeded in protecting lives. A cross and a tick represent a failure.
in warning and forecasting: a person died during an event which was not seen as posing a risk to life, hence the forecast missed the risk. A double cross, as well as a yellow tick and cross represent accurately judged warnings: no risk to life was anticipated and none occurred. The relative proportions of the matrix quadrants comments on the overall usefulness of warnings data as a measure of fatality likelihood.

8.2 Results: are warnings predictive of fatalities?

8.2.1 MetOffice National Severe Weather Warning System – Pre-2011: Nimbus dataset

Two datasets of NSWWS warnings were analysed for this study. The earlier dataset was the Nimbus dataset of severe weather flash warnings, advisory warnings, and early warnings for the period January 2008 to March 2011. At this time, warnings were not impact based and did not have clearly defined impact threshold levels, although rain, snow, blizzard, and gale events are reported as heavy, very heavy, and severe. As mentioned previously, flash warnings were triggered by high certainty events with a significant magnitude of hazard, for example more than 15 mm of rain in three hours, mean wind speeds over 40 knots, and snow accumulating at a rate of more than 2cm per hour for more than two hours (Hunt, 1989). So whilst the severity levels cannot be directly mapped onto the later impact based “traffic light” warning system, we can judge the severity of the forewarned event against others in the time period. This gives the set of results for warnings by hazard and severity presented in Table 8.2-1.

Table 8.2-1 Number of Nimbus NSWWS warnings January 2008 — March 2011: The single digits of “very heavy” and “severe” warnings for rain and snow suggests that these are the most intense events, like the red alert events of the post 2011 system. Gales seem to have a different severity definition, with only severe events warned, and many of them. The vast majority of warnings was for rainfall events, some of which could be linked to flooding, which is sometimes mentioned in the text of the warning.

<table>
<thead>
<tr>
<th>Hazard and magnitude</th>
<th>Number of warnings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Rain</td>
<td>1853</td>
</tr>
<tr>
<td>Very Heavy rain</td>
<td>7</td>
</tr>
<tr>
<td>Freezing Rain</td>
<td>6</td>
</tr>
<tr>
<td>Blizzards</td>
<td>39</td>
</tr>
<tr>
<td>Severe Blizzards</td>
<td>6</td>
</tr>
<tr>
<td>Drifting Snow</td>
<td>51</td>
</tr>
<tr>
<td>Severe Drifting Snow</td>
<td>1</td>
</tr>
<tr>
<td>Heavy Snow</td>
<td>917</td>
</tr>
<tr>
<td>Very Heavy Snowfall</td>
<td>6</td>
</tr>
<tr>
<td>Severe Gales</td>
<td>206</td>
</tr>
<tr>
<td>Severe Gales/Storms</td>
<td>3</td>
</tr>
<tr>
<td>Widespread Dense Fog</td>
<td>14</td>
</tr>
<tr>
<td>Widespread Icy Roads</td>
<td>766</td>
</tr>
</tbody>
</table>
There were at least 3875 warnings of various types and levels issued between January 2008 and March 2011. About 450 warning files were either duplicates or had formatting errors, which meant they could not be parsed from .xml files. The warnings had a stable annual frequency and a predictable geographic distribution (Table 8.2-2 and Figure 8.2-2). Rainfall is the most frequent warning trigger, with wind warnings issued much less frequently during this time period (Figure 8.2-1). Many, though not all of the rainfall warnings included descriptive text which mentioned the potential for surface water flooding. However, this information could not be effectively extracted due to the inconsistency of wording and format, and the lack of a likelihood or severity parameter in the descriptive text. To be consistent with the methodology applied in Chapter 5, for the purposes of this analysis, rainfall triggering a severe weather warning is assumed to be a likely precursor of flooding. Event lag times are accounted for in the sensitivity boundaries of the analysed report dates.

Table 8.2-2 Number of NSWWS warnings and between January 2008 and March 2011: Formatting differences made a significant portion of the 2008 warnings unusable, but most of the duplicates were removed. Scaling up the first quarter of 2011 to 12 months (349 x 4=1396) suggests that each year there is a steady count of between 1300-1400 warning files per year, including duplicates. *Represents half of the warning files, which accounts for removing most duplicates. Accounting for duplicates suggests an annual frequency of about 713 warnings issued.

<table>
<thead>
<tr>
<th>Year</th>
<th>Warnings</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>778</td>
<td>6</td>
</tr>
<tr>
<td>2009</td>
<td>1385 (693*)</td>
<td>5</td>
</tr>
<tr>
<td>2010</td>
<td>1363 (682*)</td>
<td>2</td>
</tr>
<tr>
<td>2011</td>
<td>349</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 8.2-1: NSWWS warnings by hazard type between January 2008 and March 2011: More than half of the warnings reported heavy, very heavy, or severe rainfall, potentially causing flooding. Warnings for severe wind events were fewer, which will be discussed further in this chapter. The “Other” category covers ice, fog, and other less reported events.
The early NSWWS product was not designed to communicate severity and warnings were binary, either warn or no warn (implying safety). The warnings vary in their use of the terms “severe” and “heavy”, as well as “very severe” and “very heavy”, but these do not appear to have a consistent application throughout the dataset and across different hazards.

Instead, we move on to attempting to map flood fatality dates on a time series of severe weather warnings for rainfall. Warnings are not issued every day, and multiple warnings are issued for most events, so a time series of warnings effectively highlights clusters of extreme weather events. The clustering is similar to the extreme rainfall time series in Chapter 5, but this time we add the expert assessment dimension of whether the expected rainfall was judged to be sufficiently hazardous to trigger a severe weather warning. And simultaneously, we check whether fatalities can be visually associated with peaks in warnings i.e. most extreme hazards.
Figure 8.2-3 Time series of NSWWS warnings for rain between January 2008 and March 2011 with flood fatality dates:
The number of warnings for a particular day reflects both the geographical and temporal extent of a rain hazard. Additional warnings may be issued to add affected regions, increase the severity level or the expected duration of the hazard, or to add details, such as expected flood impact. Hence they also communicate the uncertainty and complexity of the event, which requires additional warning clarification. Therefore, taller bars represent the most complex and intense events, with potential for flash floods. The density of bars represents extended periods of severe rainfall, which could lead to slower onset riverine flooding. Observing fatality markers around peaks and dark blue sections suggests a degree of causality e.g. January and September 2008, November 2009.
A greater degree of visual association between peaks and clusters of rainfall warnings and flood fatalities can be observed from Figure 8.2-3, compared to just rainfall events and fatalities presented in Chapter 5. Even without a regional breakdown, we can see that some of the deaths, including the rare incidents where two deaths were reported on the same day/event, are linked to peak or clustered weather warnings. This implies that the warnings were predictive of some of the deaths, and as a consequence probably prevented others.

Presenting more evidence of this association, Table 8.2-3 looks at individual reported fatalities, tracing regional warning contexts.

Table 8.2-3 Fatalities reported between January 2008 and March 2011, and the quantity and region of NSWWS warnings in place: A match reports an occasion when a severe weather warning for rainfall was in place in the same region as the fatality one or two days before the death was reported, accounting for flood lag time from the point of rainfall, and reporting delay. 11 fatalities out of 15 were predicted by one or more regional severe weather warnings in place. Two fatalities occurred when warnings were issued for other regions, and two were not preceded by any warnings. Regions accounted for are England: SE – South East, SW – South West, C – Central, NE – North East, NW – North West; S – Scotland; W – Wales; NI – Northern Ireland.

<table>
<thead>
<tr>
<th>Fatality Date</th>
<th>NSWWS rain warnings</th>
<th>Fatality Region(s)</th>
<th>Warning region(s)</th>
<th>Match?</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-Jan-08</td>
<td>0</td>
<td>C</td>
<td>W, SW, NW</td>
<td>NO</td>
</tr>
<tr>
<td>04-Jun-08</td>
<td>13</td>
<td>SE</td>
<td>SE, C, NE, S</td>
<td>YES</td>
</tr>
<tr>
<td>13-Aug-08</td>
<td>11</td>
<td>SW</td>
<td>SW, SE, NE</td>
<td>YES</td>
</tr>
<tr>
<td>07-Sep-08</td>
<td>10</td>
<td>SW</td>
<td>SW, C, NE, NW</td>
<td>YES</td>
</tr>
<tr>
<td>08-Sep-08</td>
<td>0</td>
<td>W</td>
<td>0</td>
<td>NO</td>
</tr>
<tr>
<td>14-Dec-08</td>
<td>4</td>
<td>SW</td>
<td>SW, SE</td>
<td>YES</td>
</tr>
<tr>
<td>20-Nov-09</td>
<td>30</td>
<td>W</td>
<td>W, S, NW, NI</td>
<td>YES</td>
</tr>
<tr>
<td>22/11/2009 2 fatalities</td>
<td>12</td>
<td>W and SW</td>
<td>SW, W, NW, S, NI</td>
<td>YES</td>
</tr>
<tr>
<td>29/11/2009 2 fatalities</td>
<td>11</td>
<td>W and SW</td>
<td>SE, SW, C, NE, W</td>
<td>YES</td>
</tr>
<tr>
<td>27-Feb-10</td>
<td>5</td>
<td>NE</td>
<td>SE, C</td>
<td>NO</td>
</tr>
<tr>
<td>23-Apr-10</td>
<td>0</td>
<td>S</td>
<td>0</td>
<td>NO</td>
</tr>
<tr>
<td>17-Jan-11</td>
<td>10</td>
<td>W</td>
<td>W, SE, SW, S</td>
<td>YES</td>
</tr>
<tr>
<td>06-Feb-11</td>
<td>7</td>
<td>W</td>
<td>W, NE, NW, S, NI</td>
<td>YES</td>
</tr>
</tbody>
</table>

From the case study analysis, we can see that 9 of the 13 fatality days (i.e. 11 deaths) can be linked to some degree of warning in the region, either one or two days before the report. This means that around the time of the victim’s death, some sort of regional severe weather warning was in effect, most likely disseminated via media channels, and probably taken up by emergency responders, undertaking action to protect lives. Four cases represent the warning system missing circumstances
which could pose risk to life, either regionally or temporally, as no warnings were in place close to the victim on the day of their tragic accident, or immediately before it.

Overall, the NSWWS alerts for the early part of the time series can be seen as predictive of most cases of flood death. There were a total of 1860 heavy and very heavy rainfall warnings during the three year and three month period, and 386 days during the period January 2008 – March 2011 had some sort of rainfall warning in place. This means that severe rainfall was warned against in one or more parts of the UK on 33% of days during the time period, but there were only 15 casualties on 13, or 0.8% of days. The high number of warnings in the context of very few deaths suggests that the warnings were effective in preventing further casualties.

Alternatively, the outcome could be indicative of a high rate of false alarms. Table 8.2-4 is a contingency table analysing NSWWS Nimbus warning days and days which saw a flood fatality.

**Table 8.2-4 2x2 Contingency table for the NSWWS Nimbus warnings January 2008 – March 2011:** The analysis is based on days during the period of the dataset as a single measure. Multiple deaths and multiple warnings on the same date are disregarded. “Hits” are judged to be the number of days when warnings and fatalities occurred together and in the same region. The dataset presents data for 1186 days, 386 of which had at least one severe rain warning issued somewhere in the country (which means that 800 days were warning free). A positive outcome is considered a low False Alarm Rate and a high Probability of Detection.

<table>
<thead>
<tr>
<th>Fatality occurred</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning issued</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>11</td>
<td>375</td>
</tr>
<tr>
<td>NO</td>
<td>4</td>
<td>796</td>
</tr>
<tr>
<td>False Alarm Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>375/(375+796) = 0.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Probability of Detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11/(11+4) = 0.73</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The False Alarm Rate and Probability of Detection values in Table 8.2-4 provide a basis for comparison of the early NSWWS data with later warnings, and with those from the FGS. The next set of analyses looks at the NSWWS impact based warnings and flood fatalities in the latter part of the study period.
8.2.2 MetOffice National Severe Weather Warning System: Post-2011 SWIFT Warnings

From April 2011 to December 2014 there were 2300 .pdf warnings published in the format presented in Figure 8.1-1. This dataset was analysed using an online parser to extract information from each warning for analysis. Warning frequency for all hazards was fairly consistent for 2012, 2013, and 2014. As Table 8.2-5 shows, much fewer warnings were issued in 2011, which may be in part explained by fewer extreme events that year, but is also partly due to the integration of legacy and new warning systems in that year.

Table 8.2-5: Number of NSWWS warnings between April 2011 and December 2014: During the transition period in 2011, it seems that fewer warnings were issued, possibly while they were still augmented by the Nimbus warnings. Almost all of the amber warnings in 2014 represent the first quarter of that year, which saw widespread flooding in the west of England.

<table>
<thead>
<tr>
<th>Year</th>
<th>All weather warnings</th>
<th>Rainfall warnings</th>
<th>Flood Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Yellow</td>
<td>Amber</td>
</tr>
<tr>
<td>2011</td>
<td>251</td>
<td>213</td>
<td>37</td>
</tr>
<tr>
<td>2012</td>
<td>755</td>
<td>665</td>
<td>87</td>
</tr>
<tr>
<td>2013</td>
<td>664</td>
<td>608</td>
<td>55</td>
</tr>
<tr>
<td>2014</td>
<td>631</td>
<td>596</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>2301</td>
<td>2082</td>
<td>213</td>
</tr>
</tbody>
</table>

Looking closer at Table 8.2-5 we can see the relative proportion of yellow, amber, and red event warnings. The majority of warnings are yellow with only a single incident each year qualifying as a red event in terms of its likelihood and impact severity. From the methodological note in 8.1.1 and the risk matrix reproduced in Figure 8.1-2, we can recall that the NSWWS system only anticipated potential risk to life at amber and red levels, which represent at least a level three on both likelihood and impact severity parameters.

Therefore, for the purposes of this analysis, we are interested in the 219 amber and red warnings, 118 of which warned against extreme rainfall with the potential to cause flooding. This represents about 9.5% of all warnings issued during the time period.

Amber warnings also tend to cluster around known major weather events, such as the west of England floods in the winter of 2014, which explain almost all of the amber warnings that year. The overall frequency of warnings, with a mean on 708 warnings per year for 2011 — 2014, is very close to that for the preceding period (713, see Table 8.2-1). This means that the overall approach
and methodology to issuing warnings was not impacted by the new system. The impact based warning classification using traffic light categories divided the warnings into a more diverse three tier system. We can also observe differences in the proportions of warnings triggered by different meteorological hazards.

![Pie chart showing the distribution of warnings by hazard type. Rain 55%, Snow 15%, Gales 13%, Other 17%.]

**Figure 8.2-4 NSWWS warnings by hazard type between April 2011 and December 2014:**
As in the previous warning period, more than half of the warnings were triggered by rainfall events, potentially causing flooding. The share of warnings about extreme wind events was larger for this time period, probably due to a number of severe wind storms in 2012. The share of snow hazard warnings is lower for this period compared to the preceding three years. The “Other” category represents ice and fog warnings. Although some of this difference can be attributed to changes in hazard classification, it is more likely that the changes reflect a different set of weather patterns between the two periods.

The new SWIFT NSWWS system has fewer classifications for weather hazards, with only three main hazard groups – rain, wind, and snow, which are reported either separately or in pairs, with the occasional warning for ice or fog. This may in part explain the drop in snow warnings, which would have featured in more combined event warnings in the previous period. However, it is more likely that the slight difference in the proportions of each hazard in the warnings dataset reflects a different weather context for the UK in this time period. This includes two wetter and warmer winters, and at least three significant wind storms (St Jude’s Day, Emily, Darwin).

Looking specifically at the rainfall warnings, which were less consistent from year to year, with many more warnings issued in 2012 than other years, **Figure 8.2-5** presents a time series of rain warning frequencies. By plotting the 15 flood fatalities over the time series, we can trace visual associations between peak or clustered rainfall alerts and flood casualties.
Figure 8.2-5: Time series of NSWWS warnings for rain between April 2011 and December 2014, with flood fatality dates:
A daily warning count represents the intensity of the rain event and the number of regions it affects. The tallest stacks reflect multiple warnings on a single day, suggesting many regions were affected by sudden and extreme events, possibly linked to flash flooding. Darker sections represent long periods of extreme rainfall impact risk, which are likely to be linked to flooding due to high levels of saturation. Observing fatality markers around peaks and clusters suggests that some can be traced to particular events and periods e.g. summer 2012, winter 2013-2014. However, others are not clearly associated with significant rainfall warnings.
There is less obvious visual association from the time series in Figure 8.2-5 between warning peaks or clusters and flood fatality dates, compared to the previous time series for 2008 – 2011 in Figure 8.2-3. Some death markers map onto the overall pattern of warning intensity, suggesting that a number of warning attempts were predictive of risk to life. This includes fatalities in the summer of 2012 and during the winter of 2013 – 2014. However, several other fatality dates seem to occur during quieter, or less extreme warning periods. To analyse this more specifically, we need to look at the warning context of each separate fatality case study.

Table 8.2-6 Fatalities reported between April 2011 and December 2014, and the quantity and region of NSWWS warnings in place one day before the report: A match represents a fatality which coincided with a severe warning of rain in the same region either one or two days before the report, to account for flood lag time after rainfall and reporting delay. About half of the flood fatalities during the period can be directly linked to rainfall warnings in place in the region at the time. Regions accounted for are England: SE – South East, SW – South West, C – Central, NE – North East, NW – North West; S – Scotland; W – Wales; NI – Northern Ireland.

<table>
<thead>
<tr>
<th>Date</th>
<th>Yellow</th>
<th>Amber</th>
<th>Red</th>
<th>None</th>
<th>Fatality region</th>
<th>Warning region</th>
<th>Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/07/2011</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>S</td>
<td>S, NW, NE</td>
<td>YES</td>
</tr>
<tr>
<td>17/07/2011</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>S</td>
<td>S, NW, NE</td>
<td>YES*</td>
</tr>
<tr>
<td>26/12/2011</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>W</td>
<td>S</td>
<td>NO</td>
</tr>
<tr>
<td>29/04/2012</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>SE</td>
<td>W, SE, NW</td>
<td>YES</td>
</tr>
<tr>
<td>28/06/2012</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>C</td>
<td>S, C, NE, NI</td>
<td>YES</td>
</tr>
<tr>
<td>27/09/2012</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>W</td>
<td>SE</td>
<td>NO</td>
</tr>
<tr>
<td>28/09/2012</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>W</td>
<td>SE</td>
<td>NO</td>
</tr>
<tr>
<td>27/11/2012</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>SW</td>
<td>NE, W, C, NW</td>
<td>NO</td>
</tr>
<tr>
<td>29/11/2012</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>W</td>
<td>-</td>
<td>NO**</td>
</tr>
<tr>
<td>25/03/2013</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>SW</td>
<td>-</td>
<td>NO</td>
</tr>
<tr>
<td>25/12/2013</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>NE</td>
<td>NE, SW</td>
<td>YES</td>
</tr>
<tr>
<td>26/12/2013</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>SW</td>
<td>NE, SW</td>
<td>YES*</td>
</tr>
<tr>
<td>27/12/2013</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>W</td>
<td>W, NE, NW, S, SW, SE, NI</td>
<td>YES</td>
</tr>
<tr>
<td>06/01/2014</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>SE</td>
<td>S, NW, E, SE, SE</td>
<td>YES</td>
</tr>
<tr>
<td>10/02/2014</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>SE</td>
<td>-</td>
<td>NO***</td>
</tr>
</tbody>
</table>

*Explained by the incident immediately preceding, i.e. warning issued two days before the fatality report, and likely linked.
**There were 20 warnings in the preceding 3 days, including 4 ambers, all around the country, including Wales, so when the victim’s car was dragged under by a swollen ford, the flood conditions had already been in place for some time, with amber warning four days previously, so could be a late reporting artefact, victim died when a landslide triggered by torrential rain and flooding, destroyed her house.
***This was the flood pump CO poisoning, so longer lag time from the winter floods, which saw the greatest frequency of significant warnings.

Compared to the four un-warned deaths in the previous time period, this analysis shows that about half of the fatalities had no relevant warning context (in the region or on the day). Looking further at particular cases, several can be explained as artefacts of the reporting method or were otherwise forewarned. One death in November 2012 has no specific warning linked to it: on this occasion a
77-year-old man drowned in his car when it was swept up by a swollen ford which he attempted to drive across. What we can see from the warning database, is that multiple yellow and amber warnings, with suggestions of flood impacts were issued that week all across the country. Although there was no further rain immediately preceding this death, flood conditions still prevailed, which can be confirmed by the yellow Flood Guidance Statement that date, and the eight amber days before it. Similarly, the absence of a warning on the 10th of February 2014 when a seven-year-old boy died from carbon monoxide poisoning as a flood pump worked in his home, is a direct impact of the numerous forewarned winter 2014 rain and flood events. Tellingly, the FGS that day was red.

However, five of the fatality deaths still remain far from severe weather warnings, either temporally or geographically, which suggests that during this period weather warnings were less predictive of flood fatalities. On the other hand, three of the seven missing fatality dates can be traced to amber level FGS days. Although we cannot use the FGS dataset to identify the region of the flood, only its occurrence, the observation that flood deaths happened during flood warnings is pertinent, even if their regions do not coincide.

Another important observation is that the association between rainfall warnings and fatality dates is almost exclusively categorised by yellow level warnings. No one died during a rare red alert, and only two deaths are linked with single amber warnings in place, amongst multiple yellow ones. Considering that only amber and red NSWWS warnings relate to risk to life, we can conclude that they are largely preventative of flood death. Yellow warnings, which do not directly communicate potential fatal impacts, coincide with more incidents of death from drowning.

To explore the effectiveness of the warnings, Table 8.2-7 presents False Alarm Rate and Probability of Detection calculations for this part of the NSWWS dataset. Given the different definitions of risk to life, the table explores the effectiveness indicators for Yellow-Amber-Red and Amber-Red separately.
Chapter 8  The Protective Effect of Warnings

Table 8.2-7 2x2 Contingency table for the NSWWS warnings March 2011 – December 2014, a) with yellow-amber-red warnings, and b) with amber-red only: The analysis is based on days during the period of the dataset as a single measure. Multiple warnings on the same date are disregarded. “Hits” are judged to be the number of days when warnings and fatalities occurred together and in the same region. There dataset presents data for 1371 days, 496 of which had at least one yellow, amber or red severe rain warning issued somewhere in the country (this means that 875 days had no warning at all). Considering only red and amber warnings, only 58 days counted one or more of these severe alerts, meaning 1313 days did not have a “risk to life” level warning. Margins are given for fatalities, as the number of “hits” depends on the interrogation of the dataset – the described match method returns the lower value, but manual interrogation of the database finds explanations for two extra fatalities. For the FAR and POD calculations, the median is taken. A positive outcome is considered to be a low False Alarm Rate and a high Probability of Detection.

a) Fatality occurred

<table>
<thead>
<tr>
<th>Yellow, Amber or Red warning issued</th>
<th>Fatality occurred</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES 5 ≤ x ≤ 7</td>
<td>8 ≤ x ≤ 10</td>
</tr>
<tr>
<td>869</td>
<td>485</td>
</tr>
<tr>
<td>False Alarm Rate</td>
<td>485/(485 + 869) = 0.35</td>
</tr>
<tr>
<td>Probability of Detection</td>
<td>9/(6 + 9) = 0.6</td>
</tr>
</tbody>
</table>

b) Fatality occurred

<table>
<thead>
<tr>
<th>Amber or Red warning issued</th>
<th>Fatality occurred</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES 2 ≤ x ≤ 4</td>
<td>13 ≤ x ≤ 11</td>
</tr>
<tr>
<td>55</td>
<td>1301</td>
</tr>
<tr>
<td>False Alarm Rate</td>
<td>55/(55 + 1301) = 0.04</td>
</tr>
<tr>
<td>Probability of Detection</td>
<td>3/(3 + 12) = 0.2</td>
</tr>
</tbody>
</table>

The analysis of the Probability of Detection and False Alarm Rate for the later NSWWS warnings, which are impact based, is split into two. The top part of Table 8.2-7 analyses all of the NSWWS SWIFT warnings for rainfall for the period – yellow, amber, and red. At this level, we observe that the False Alarm rate of 0.35 is very similar to that of the NSWWS Nimbus warning set (0.32). This is explained by a broadly similar frequency of warnings and number of extreme rainfall events representing a fairly constant weather pattern in the UK, while deaths from flooding remained consistently low during both periods, whether forewarned or not. However, by only considering amber and red warnings, which explicitly warn against a risk to life, the SWIFT system demonstrates a negligible False Alarm Rate of 0.04, indicating that this level of warning is very rare and accurate. But the Probability of Detection of a fatality is also very low for ambers and reds (0.2), with far more
casualties occurring during an active yellow warning – POD (0.6), or even no warning at all. This suggests that the earlier Nimbus warning protocol was actually more predictive at detecting weather events that posed a risk to life (POD = 0.73) than the later impact based and traffic light differentiated warnings. The significant caveat associated with this finding is that we do not have a measure for avoided fatalities i.e. the closeness of the Probability of Detection to the perfect score of one does not describe the overall effectiveness of the system as many issued warnings which would be classified as “false alarms” may have actually deterred people from going outside in hazardous weather, thus preventing fatalities.

Roughly half of the fatalities during this period are not associated with a temporally and spatially co-located rainfall warning. However, the FCC’s Flood Guidance Statement, which incorporates NSWWS information and combines it with catchment level data, may well explain some of the un-warned fatalities for the period.

### 8.2.3 FFC warnings

Following the analysis of severe weather warnings, the FCC FGS calendar extract data was examined and matched up with the flood fatalities dataset. FGS data is available for four years: 2011, 2012, 2013, 2014. The flood level warnings anticipated by the FGS can augment the findings of the NSWWS SWIFT dataset for the period. Consulting the flood fatalities database shows that 17 deaths occurred during this time period. Table 8.2-8 presents the breakdown of warnings and fatalities by year.
Table 8.2-8 Total number of FFC FGS calendar warnings and flood fatalities for the period 2000 — 2014: The number of days in each year at each flood risk warning level. The large number of red and amber warnings in 2014 almost entirely reflects the January-March 2014 period which saw widespread flooding in the west of England and two deaths. The other high warning level days are more spread out, with some amber clustering July and November 2012. There is no trend between fatalities and rising and falling risk levels, although we know there were few flood casualties during the 2014 winter floods, and none in the worst affected regions in the west of England (victims died in Oxford and Surrey), as these were relatively slow onset events.

<table>
<thead>
<tr>
<th>Year</th>
<th>Green</th>
<th>Yellow</th>
<th>Amber</th>
<th>Red</th>
<th>Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFC risk to life *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal Impacts – Not expected</td>
<td>Minor impacts - Individual risk for the more vulnerable or for those making decisions in unfamiliar situations</td>
<td>Significant impacts - Danger to life from fast flowing / deep water / wave overtopping / wave inundation and physical hazards</td>
<td>Severe impacts - Danger to life from fast flowing / deep water / wave overtopping / wave inundation and physical, chemical or utility hazards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>275</td>
<td>84</td>
<td>6</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>2012</td>
<td>192</td>
<td>127</td>
<td>45</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>2013</td>
<td>246</td>
<td>109</td>
<td>8</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2014</td>
<td>160</td>
<td>135</td>
<td>36</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>873</td>
<td>455</td>
<td>95</td>
<td>38</td>
<td>17</td>
</tr>
</tbody>
</table>


The first and clearest conclusion is that there are very few fatalities in any warning context, be it a year with a high number of severe warnings, or not. Also, the low numbers of fatality do not follow any particular pattern in relation to the change in warnings annually. From the warnings data, we can trace anomalous high warning frequencies to specific events or periods, such as all of the 34 red warnings and 33 out of 36 amber warnings in 2014 all falling into the first three months of the year, which saw widespread and long standing flooding in the west of England.
Figure 8.2-6 Green, Yellow, Amber, and Red FGS warning days for the period 2011 – 2014: On 60% of days there were no flood warnings anywhere in the country, therefore we don’t anticipate to match flood fatality reports to 60% of the FGS dataset. However, a third of days during the period saw a yellow warning issued somewhere, which in the case of FGS warnings represents an individual risk to life for vulnerable people or those finding themselves in unfamiliar circumstances. This is a significant proportion of the year, indicating that flood risk in the UK is a substantial hazard. We can see a close to geometric reduction in the frequency of each level of warning.

With some kind of flood warning in place somewhere in the UK on 40% of all days during the time period, we can expect a certain level of risk on an average of 146 days of the year. This indicates that there are substantial opportunities of some level of impact and risk to life: and the strikingly low number of fatalities shows that there are numerous avoided risks, probably achieved by the institutional protection systems activated by these warnings through Category 1 and 2 emergency responders.

Looking specifically at the 17 flood deaths during this time period presents the number of death in at each warning severity level in Table 8.2-9.
Table 8.2-9 FGS warning days in each severity category for 2011 — 2014 and the total number of flood fatalities associated with each level of warning: Date 0 is the day the fatality was reported, Date -1 and Date -2 refer to the two days prior to the report. Most fatalities are reported the following day, so Date -1 is probably the strongest indicator: in this case warnings on Date -1 it match 11 out of 17 fatality dates. The fall in both warnings and fatalities at each impact severity threshold is noticeable and represents about 50% for most boundaries. At least five fatalities occurred when there were no yellow or above FGSs anywhere in the country.

<table>
<thead>
<tr>
<th>FGS warnings</th>
<th>Date -1</th>
<th>Date -2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>873</td>
<td>5</td>
</tr>
<tr>
<td>Yellow</td>
<td>455</td>
<td>5</td>
</tr>
<tr>
<td>Amber</td>
<td>95</td>
<td>5</td>
</tr>
<tr>
<td>Red</td>
<td>38</td>
<td>1</td>
</tr>
</tbody>
</table>

Taking into account the fact that a dataset of 17 cases is not a significant number for drawing conclusions about trends, a number of high level observations can be made. Firstly, at least five deaths were not predicted or prevented by any warning anywhere in the country, and in most of those cases, there was no advance warning in place. These cases report tragic accidents in low risk contexts, when flood waters were still, or suddenly high. However, they show that warnings are not one hundred percent effective at preventing fatalities.

Secondly, roughly the same number of fatalities occurred during yellow and amber warning periods, whereas we might expect the amber warning to mobilise more significant protection systems and protect more lives. In this analysis, we can assume that amber warnings, which caution explicitly against danger to life from flowing water, and yellow warnings, which only predict individual, vulnerable, and accidental death, are as effective as each other at preventing and anticipating casualties. However, as we have no method for counting avoided fatalities, we cannot suggest a baseline against which the amber level of protection was preventative.

Finally, the deaths which occurred during the red warning period in January 2014 was the single direct flood casualty – a 47-year-old man, whose mobility scooter fell into a swollen river as he was trying to cross a flooded pathway in Oxford. Considering the risk to life communicated by a red level warning, the single casualty reflects the overall success for the warning system in place, despite the tragic outcome of the case study.
Table 8.2-10 presents the False Alarm Rate and Probability of Detection achieved by FGS yellows, ambers and reds, with the caveat that the degree of spatial detection could not be considered as no regional information on FGSs was available in the dataset.

Table 8.2-10 2x2 Contingency table for the daily Flood Guidance Statements 2011 – 2014, national level: The analysis is based on FGS calendar days, 1460 in total for the period. “Hits” are judged to be the number of days when warnings and fatalities occurred together. 588 days had a yellow or above Flood Guidance Statement issued somewhere in the country. This means that 866 days were Green for flooding (very similar to the figure of 875 days without any rainfall warning identified for the previous dataset). A positive outcome is considered to be a low False Alarm Rate and a high Probability of Detection.

<table>
<thead>
<tr>
<th>Fatality occurred</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning issued</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>11</td>
<td>577</td>
</tr>
<tr>
<td>NO</td>
<td>6</td>
<td>866</td>
</tr>
<tr>
<td>False Alarm Rate</td>
<td>577/(577+866) = 0.4</td>
<td></td>
</tr>
<tr>
<td>Probability of Detection</td>
<td>11/(11+7) = 0.65</td>
<td></td>
</tr>
</tbody>
</table>

Calculating the Probability of fatality Detection and False Alarm Rate for fatalities forewarned by Flood Guidance Statements shows that the overall rates are similar to those for the other two datasets. In theory, the FGS and the later NSWWS should complete one another, filling in misses and gaps to account for reporting delays and flood lag times. However, in reality the two systems have a similar rate of “misses” i.e. fatalities which did not occur in the context of a warning. It could also have been speculated that the FGS will have a better “hit” rate because without any regional data available at the FGS calendar level fatalities which were classified as “missed” by NSWWS due to the warning being issued far away, would be “caught” by the national scale of the FGS data. However, here too the rates are very similar, even accounting for sensitivities and median values.

In considering the Probability of Detection of a fatality by an FGS, we need to remember that where fatalities were not detected because they did not happen the warning may well have had a protective effect. Overall, the FGS flood warning numbers, and their intersections with dates of flood fatalities, show that this warning system is effective at anticipating fatal impacts and protecting lives when flood risk is acknowledged. However, the system also misses events or circumstances which turned out to be fatal due to accidental or behavioural factors. Not all swollen watercourses triggered
a flood warning, meaning a handful of lives were lost without Category 1 and 2 responders actively dealing with the risk.

### 8.2.4 Analysing the three warning datasets together

Using the total number of days in the study period which return a particular level of warning, and report a death, allows for a comparative analysis of the three datasets by the Probability of Detection of a fatality by a warning in place, and by the False Alarm Rate of risk to life. Whilst Table 8.2-11 presents the closest possible like-for-like comparison of the datasets, two caveats need to be reiterated. Firstly, that the FGS data is not regionally coded, giving it, in theory, a greater chance of detecting a fatality anywhere in the country. And secondly, that semantically yellow NSWWS warnings should not be considered as predictors of risk to life, as only amber and above are described to consider this a likely impact.

#### Table 8.2-11 Probability of Detection and False Alarm Rates for the occurrence of flood fatalities by the three warning systems investigated:

<table>
<thead>
<tr>
<th>Warning System</th>
<th>Probability of Detection of flood fatality</th>
<th>False Alarm Rate for flood fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSWWS Nimbus 2008 – 2011</td>
<td>0.73</td>
<td>0.32</td>
</tr>
<tr>
<td>NSWWS SWIFT 2011 – 2014</td>
<td>0.6 (amber/red only:0.2*)</td>
<td>0.35 (amber/red only:0.04*)</td>
</tr>
<tr>
<td>Flood Guidance Statement</td>
<td>0.65</td>
<td>0.4</td>
</tr>
</tbody>
</table>

The results show that for all three systems, the Probability ofDetection of a fatality is greater than the False Alarm Rate of warnings of risk to life. This means that the systems are broadly accurate in terms of forewarning circumstances which may, and have, led to death from flooding. They also show that the rates for all three systems are broadly similar, suggesting that their application has been consistent over the period.

The practical application of POD values seeks for a maximisation of this value towards one. This parameter suggests that the early NSWWS (POD = 0.73) was a more predictive system than the late, impact based and traffic light system NSWWS (POD = 0.6). However, unlike the verification process for meteorological forecasting, where “hits” and “misses” are categorical and linked, the
absence of a flood fatality does not necessarily indicate that the warning was a false alarm, in the sense of there being no actual hazard impact. In fact, if we take a utilitarian view of forecasting, as a method of protection from harm, we could speculate that the False Alarm Rate, when nobody died, represents a successful warning outcome, where no risk to life was actualised because warnings were heeded.

However, missed fatalities, when no warning was in place but a fatality occurred, are a problem for the forecasting systems as they represent a failure to protect. The number of missed flood fatalities over a four year period is also fairly similar between the datasets: Nimbus = 4, SWIFT = 5, FGS = 6. These are the numbers driving the difference in POD, and it is the “misses” that present the greatest interest in term of policy outcomes. Interestingly, if the disambiguation of the impact severity traffic lights for impact based NSWWS warnings is taken literally, the “miss” rate of this system rises dramatically and its POD falls to 0.2.

With all this in mind, it is worth attempting to unpack the contingency table further, by redefining false alarms in terms of their protective potential, i.e. a heeded waring, and the absence of warnings and fatalities as the “correct negatives” that they are, using the NOAA definition (NOAA, 2005).

Using the warning totals from each analysed dataset, we return to the matrix presented at the start of the chapter. By counting the number of warnings, at different levels, which do or do not coincide with fatality dates (-2 days) we can make an assessment of the effectiveness of warnings in predicting, and potentially preventing deaths from flooding. The completed matrix analysis is presented in Table 8.2-12. It should be noted that comparison between systems is tricky as the warnings are not like for like datasets; each system’s results are telling in their own right, and some cautionary observations about the effectiveness of each system can be made.
Table 8.2-12 Completed analysis matrix for warnings and fatality data: The number of warnings issued by each system, which do or do not coincide with flood death dates are tallied up in the matrix. NSWWS Nimbus warnings, which do not have a “traffic light” severity categorisation are reported as yellow (heavy/severe events) and amber (very heavy/very severe), but this distinction should be taken as arbitrary. Double ticks represent predictive events, where warnings at various levels and flood fatalities coincide by their date. A tick and a cross represent protective warnings: where a warning was in place and no one died on that day. A cross and a tick represent missed casualties: where a fatality occurred when no warning was issued that day, or the FGS was green. Double crosses represent low risk flood days (FGS green days) and days on which there were no weather warnings at all and no fatality.

<table>
<thead>
<tr>
<th>Warning: yellow</th>
<th>Fatality</th>
<th>No Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✔✔ correct/predictive</td>
<td>✔ X correct/protective</td>
</tr>
<tr>
<td>FGS</td>
<td>6</td>
<td>FGS 496</td>
</tr>
<tr>
<td>Nimbus (heavy / severe)</td>
<td>177</td>
<td>Nimbus (heavy / severe) 1747</td>
</tr>
<tr>
<td>SWIFT</td>
<td>37</td>
<td>SWIFT 1107</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Warning: amber</th>
<th>Fatality</th>
<th>No Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✔✔ Predictive</td>
<td>✔ X Protective</td>
</tr>
<tr>
<td>FGS</td>
<td>5</td>
<td>FGS 90</td>
</tr>
<tr>
<td>Nimbus (very heavy/severe)</td>
<td>6</td>
<td>Nimbus (very heavy/severe) 1</td>
</tr>
<tr>
<td>SWIFT</td>
<td>5</td>
<td>SWIFT 111</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Warning: red</th>
<th>Fatality</th>
<th>No Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✔✔ Predictive</td>
<td>✔ X Protective</td>
</tr>
<tr>
<td>FGS</td>
<td>1</td>
<td>FGS 37</td>
</tr>
<tr>
<td>Nimbus n/a</td>
<td>0</td>
<td>Nimbus n/a 0</td>
</tr>
<tr>
<td>SWIFT</td>
<td>0</td>
<td>SWIFT 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No warning: green FGS or clear days</th>
<th>Fatality</th>
<th>No Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X ✔ Missed</td>
<td>X X Correct negatives</td>
</tr>
<tr>
<td>FGS</td>
<td>7</td>
<td>FGS 866</td>
</tr>
<tr>
<td>Nimbus</td>
<td>4</td>
<td>Nimbus 798</td>
</tr>
<tr>
<td>SWIFT</td>
<td>5</td>
<td>SWIFT 875</td>
</tr>
</tbody>
</table>

A series of observations can be made from examining the matrix table. Firstly, and in keeping with the previous chapters, we can conclude that the signal for a trend between the warning parameter and flood death is weak. The matrix explicitly highlights incidents of association, but essentially we are looking at fewer than 30 deaths over seven years in the context of an abundance of warning activity. The greatest number of warnings for each system are yellow alerts which were in place when no casualties occurred. This top right corner of the matrix suggests two conclusions: firstly, the overall approach to severe weather forecasting is sufficiently precautionary to account for
events which are unlikely to pose a risk to life, and secondly most of these warnings are accurate in assuming that there will be no such risk. In the case of FGS warnings, although some vulnerable or isolated lives may have been at risk, sufficient disaster management systems were mobilised to prevent death.

On the opposite side of this quadrant is the yellow warning/fatality association. Interestingly, for this and for green FGS warnings we observe the greatest number of fatalities – these are the deaths that the FGS warnings “missed”. Ex-post analysis shows that risk to life was in fact applicable to these case study situations, and we can make a cautionary observation that systems of protection mobilised by the yellow warnings were insufficient in protecting the seven lives lost on these dates. For yellow severe weather warnings, less than 5% coincide with a fatality. These are the warnings which are disseminated via the media and likely to be picked up by people in the affected regions, although there is no way of knowing whether they saw them. Tentatively, we can suggest that some of the victims at the time of yellow warnings saw them and did not perceive them as indicative of particularly perilous conditions. Or, in fact, that the message of the yellow severe weather warnings, which does not specify risk to life, was not potent enough to transmit via communication channels with sufficient reach. In any case, severe weather warning can be predictive of flood fatality roughly 3% — 6% of the time, which is not sufficient for an indicator of mortality.

A different conclusion can be drawn from amber warnings. The vast majority of FGS amber days (90 out of 95) were associated with no fatalities, making these warnings a good indicator that lives would be protected. For the five amber flood warnings which did provide context for a casualty, their assessment of a risk to life was accurate. A fatality was associated with all but one “very severe/very heavy” rain warnings before April 2011, making this tool at the amber level a strong predictor of fatalities. Arguably, we can assess the later NSWWS amber warnings as protective, because no deaths were reported when more than 96% of these were active.

Red level warnings are rare, and fatalities during these are event rarer still. We can assume that a red warning is associated with weather so severe, that people are less likely to make decisions that expose them to risk, and protection systems are fully mobilised, mitigating risk to life.

More than half of the days in each time period were without any warnings, i.e. predicted to be dry and safe. Unfortunately, these days saw about as many flood casualties as the amber warning
days. Therefore, we reach the conclusion, that while warnings at amber levels do seem to both predict deaths and protect lives, the overall severe weather warning system, and the Flood Guidance Statement are limited in their effectiveness to judge all risk to life, and to protect all lives at risk.

**8.3 Discussion**

The analysis of the warning datasets has generated three main conclusions: that deaths from flooding are very rare in the context of warning frequency; that amber warnings are serious warnings and can be used both as an indicator of likely casualties, and as an example of fatalities avoided through effective warnings; and, that yellow warnings are not predictive of fatalities and “miss” flood deaths in the same pattern as the absence of warnings does. Very similar “miss” frequencies and tangible casualty numbers recorded when yellow warnings are in place, or when no warnings are issued. This could be because yellow warnings are not communicated as strongly, meaning that there is less awareness of them in place. Alternatively, it could suggest that the perception of yellow warnings as not serious causes them to be ignored by individuals putting themselves in perilous circumstances where they take unnecessary risks.

Similarly to the analysis of rain event typologies Chapter 5, we see warning frequencies reflect the intensity and duration of rainfall. Also, similarly to the rainfall analysis, we see very few fatal incidents against a backdrop of a multitude and variety of warning. And finally, much as with the rainfall calculations, the forecast of events as extreme and high impact explains about two thirds of the flood fatalities. Primarily this means that warnings and forecasts are accurate and match weather events quite precisely. However, in the case of about 30% of flood deaths between 2008 and 2014, the warning was wrong, absent, or far from the location of the accident.

In the context of overall warning accuracy, the next best explanation for the third of un-warned victims is behavioural. Their meteorological context and immediate flood risk was assessed as low and safe, but flood waters may not have fully subsided, and localised flooding was still occurring, roads and fords may have remained perilous, and watercourses swollen and rapid. Yet despite low level or unexpired warnings, the victims put themselves at risk engaging in outdoor activities, driving through water of indeterminable depth, or taking other decisions, which increased their exposure.
For about 20% of casualties, yellow warnings were not enough of a deterrent. Alternatively, they may simply not have seen the warnings in place. By looking at these relative proportions, we can conclude that in terms of risk to life, red FGS warnings and amber NSWWS warnings must not be ignored. However, the prevalence of yellow NSWWS warnings on fatality days suggests that they were misinterpreted, disregarded, or simply unobserved by the victims.

The number of casualties reported to have occurred during yellow warnings suggests that this severity level ought to be reinterpreted to include risk to life at the individual level, like in the Flood Guidance Statement. Almost all of the fatalities in the database represent individual casualties of contextually or circumstantially vulnerable people, often facing unfamiliar circumstances, which is very close to the definition of yellow level risk to life in the FGS: “Individual risk for the more vulnerable or for those making decisions in unfamiliar situations (e.g. when crossing fords or rescuing pets)” (Flood Forecasting Centre, 2017, pp.6).

**Figure 8.3-1** Relative proportions of clear and fatality-linked warnings in each system:
Nimbus issued the most warnings and crossed over with the most fatality dates. The other systems seem to follow a similar pattern of proportions. This suggests that there is no effect of a greater number of warnings issued on their likelihood to predict or prevent fatalities. Flood deaths will represent a small percentage of any warning dataset, regardless of its size.

It would be too simplistic to suggest that there were insufficient warnings issued to account for the 11 un-warned casualties. The three warning systems analysed issued different amounts of alerts and yet all intersected with a similar percentage of casualties, as can be seen from Figure 8.3-1. And much more fundamentally, there is a vast number of rain alerts issued every year, making the diminutive number of flood fatality incidents a small and insignificant blip on their time series.
A slightly different story can be traced by looking at other potentially fatal hazard events, which are warned against less frequently and where a number of casualties may send a stronger signal of causality or lack thereof. To illustrate this, we will take a small detour into the story of severe wind storms, their warnings and fatalities.

8.3.1 Severe wind event warnings and fatalities

Chapter 4 reported fatalities from weather events other than flooding. A brief assessment showed that while deaths in storms and floods have similar patterns – or an absence of patterns – in geography and demography, deaths in high winds are even less predictable. At the same time, extreme wind events are rarer in the UK than severe rainfall, and in many ways trickier to forecast. This makes wind events, and their associated casualties, a good illustrative case to explore the association between warnings and casualties.

Table 8.3-1: Number of extreme wind event warnings issued by NSWWS between April 2011 and December 2014: The warning frequencies are much lower than those for floods, amber warnings represent a greater proportion of all warnings.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total</th>
<th>Yellow</th>
<th>Amber</th>
<th>Red</th>
<th>Wind Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>64</td>
<td>44</td>
<td>19</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>2012</td>
<td>35</td>
<td>28</td>
<td>6</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2013</td>
<td>99</td>
<td>83</td>
<td>16</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>2014</td>
<td>98</td>
<td>84</td>
<td>13</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>296</td>
<td>239</td>
<td>54</td>
<td>3</td>
<td>25</td>
</tr>
</tbody>
</table>

There are dramatically fewer severe wind warnings than severe rainfall warnings, primarily because it is a rarer hazard type for the UK. At the same time, the relative proportion of amber warnings is much higher, at 18% of all warnings issued. This suggests that when wind events do strike the country, they are much more likely to be severe, posing a risk to both lives and livelihoods.

At the same time, the number of casualties associated with high winds for the latter NSWWS time period in substantially higher at 25, compared to the 15 flood deaths. And multi fatality events are a greater feature of this hazard type, with two deaths reported on two occasions, and one event claiming four lives on the same day (St Jude’s Day storm, October 2013).

The significant jumps between total numbers of warning from 2011 to 2012 and again to 2013 suggests that the wind storms are less cyclical and predictable than severe rainfall, which is
consistent with their meteorological nature. Less frequent, harder to forecast, more likely to be severe, and responsible for a greater number of casualties, it seems that this hazard poses a greater level of risk to life in the UK, even if it occurs less often.

To analyse the effectiveness and protectiveness of forecasting severe wind storms, a similar case study level analysis was conducted for wind fatalities, presented in Table 8.3-2. Deaths in severe gales are mostly the result of blunt trauma from falling trees, masonry, or other heavy objects. Easy goods vehicle accidents are also common in high winds. A few incidents report deaths inside homes, but these can mostly also be linked to falling trees crushing caravans or causing gas explosions. Therefore, indoor/outdoor activities and mobile populations drive these numbers, just as they do with flooding. However, the age and gender distribution is less stark, with a greater proportion of women dying from these sudden, barely predictable impacts.

**Table 8.3-2 Fatalities from wind events reported between April 2011 and December 2014, and the number and geography of warnings in place:** The date before the fatality was reported (Date -1) is used as the baseline fatality date as most reports describe casualties who died the day before. 14 out of 25 deaths can be directly linked to wind warnings in place in the region at the time. Two more (purple) can be explained by analysing adjacent days. Regions accounted for are England: SE – South East, SW – South West, C – Central, NE – North East, NW – North West; S – Scotland; W – Wales; NI – Northern Ireland.

<table>
<thead>
<tr>
<th>Fatality Date</th>
<th>Yellow</th>
<th>Amber</th>
<th>Fatality Region</th>
<th>Warning region</th>
<th>Match</th>
</tr>
</thead>
<tbody>
<tr>
<td>06/02/2011</td>
<td>0</td>
<td>0</td>
<td>C</td>
<td>NO*</td>
<td></td>
</tr>
<tr>
<td>15/02/2014</td>
<td>3</td>
<td>2</td>
<td>SE C, SW, SE, W</td>
<td>YES**</td>
<td></td>
</tr>
<tr>
<td>10/03/2011</td>
<td>0</td>
<td>0</td>
<td>C</td>
<td>NO*</td>
<td></td>
</tr>
<tr>
<td>23/05/2011</td>
<td>2</td>
<td>2</td>
<td>S</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>26/05/2011</td>
<td>0</td>
<td>0</td>
<td>S</td>
<td>NO****</td>
<td></td>
</tr>
<tr>
<td>12/09/2011</td>
<td>2</td>
<td>7</td>
<td>S</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>14/07/2012</td>
<td>0</td>
<td>0</td>
<td>SE C, SW, SE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>04/01/2013</td>
<td>0</td>
<td>0</td>
<td>SE C, SW, SE</td>
<td>NO*</td>
<td></td>
</tr>
<tr>
<td>29/01/2013</td>
<td>5</td>
<td>0</td>
<td>SE NE, SE, SW, W</td>
<td>YES***</td>
<td></td>
</tr>
<tr>
<td>25/03/2013</td>
<td>0</td>
<td>0</td>
<td>SE C, SW, SE</td>
<td>NO*</td>
<td></td>
</tr>
<tr>
<td>21/04/2013</td>
<td>0</td>
<td>0</td>
<td>S</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>29/10/2013</td>
<td>4</td>
<td>5</td>
<td>SE C, SW, SE</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>04/12/2013</td>
<td>3</td>
<td>2</td>
<td>C S, NE, C, NI</td>
<td>YES****</td>
<td></td>
</tr>
<tr>
<td>06/12/2013</td>
<td>3</td>
<td>2</td>
<td>S S, NE, C, NI</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>17/12/2013</td>
<td>4</td>
<td>1</td>
<td>NI S, SE, W</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>09/02/2014</td>
<td>0</td>
<td>2</td>
<td>NI SE, C, SW</td>
<td>NO**</td>
<td></td>
</tr>
<tr>
<td>06/10/2014</td>
<td>6</td>
<td>0</td>
<td>NE or C S, SW, W</td>
<td>NO</td>
<td></td>
</tr>
<tr>
<td>21/10/2014</td>
<td>5</td>
<td>0</td>
<td>SE C, S, NI, NE, NW</td>
<td>YES</td>
<td></td>
</tr>
</tbody>
</table>

* no wind warnings all month; **2 days prior, ***on report day, ****attributable to the adjacent event
Overall, fewer wind warnings were in place on fatality dates, but their regional extent was greater. This is explained by the greater footprint of wind storms compared to pockets of severe rainfall and localised flooding. The regional extent of the warnings means that roughly the same proportion of fatalities as with flooding – 16 out of 25, or two thirds – can be explained (predicted) by a warning in place. Numbers of yellow and amber warnings associated with each casualty are low for both levels of risk, and much more similar to each other, suggesting a lesser degree of predictive ability for amber wind warnings.

### Table 8.3-3 2x2 Contingency table for the NSWWS severe wind warnings March 2011 – December 2014:

The analysis is based on NSWWS issued days, 1371 in total for the period. “Hits” are judged to be the number of days when warnings and fatalities occurred together. 96 days had a yellow or above warning for wind events. This means that 1275 days had no warning at all, which is much higher than the comparative number of “clear” days for rain and floods. A positive outcome is considered to be a low False Alarm Rate and a high Probability of Detection.

<table>
<thead>
<tr>
<th></th>
<th>Fatality occurred</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warning issued</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>NO</td>
<td>9</td>
<td>1266</td>
</tr>
<tr>
<td><strong>False Alarm Rate</strong></td>
<td></td>
<td>80/(80+1266) = 0.06</td>
</tr>
<tr>
<td><strong>Probability of Detection</strong></td>
<td></td>
<td>16/(16+9) = 0.64</td>
</tr>
</tbody>
</table>

Looking at the Probability of wind fatality Detection and the False Alarm Rate of fatal gale warnings in Table 8.3-3, we can see that the POD is very similar to that of the NSWWS rainfall data: 0.64 for wind, 0.6 for flood death. However, the significantly lower number of warnings in total, due to the much lower frequency of severe gales in the UK, compared to rainfall, drives a much lower False Alarm Rate for death prediction at 0.06, which is only similar to the amber and red rainfall FAR (0.016). This comparison tells us that the UK experiences lots of rain events, very few of which are dangerous to life. However, the residual flood deaths that we do observe are likely to happen during events which we do not forecast to be particularly dangerous. The opposite is true of gale hazards; fewer severe impact events occur, but we have fewer false alarms, representing a greater risk to life from this hazard, and a lower level of protection from warnings, if we interpret false alarms as warnings heeded and deaths avoided. To illustrate this more fully, an analysis matrix for wind warnings and deaths is presented in Table 8.3-4.
Table 8.3-4 Completed analysis matrix for wind warnings and wind fatality data: The number of wind warnings issued at each level on fatality days and safe days are tallied up in the matrix. Double ticks represent predictive events, where warnings at various levels are associated with a wind fatality on that date/region. A tick and a cross represent protective warnings: where a warning was in place and no one died on that day. A cross and a tick represent missed casualties: where a fatality occurred when no warning was issued that day. Double crosses represent low risk days on which there were no wind warnings at all and no wind fatality.

<table>
<thead>
<tr>
<th>Wind warning: yellow</th>
<th>Wind Fatality</th>
<th>No Wind Fatality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>✔✔ accurate/predictive</td>
<td>✔X accurate/protective</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>219</td>
</tr>
<tr>
<td>Wind warning: amber</td>
<td>✔✔ predictive</td>
<td>✔X Protective</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>42</td>
</tr>
<tr>
<td>Wind warning: red</td>
<td>✔✔ predictive</td>
<td>✔X Protective</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>No wind warning</td>
<td>✔X Failed</td>
<td>XX Accurate</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1263</td>
</tr>
</tbody>
</table>

We may have expected a different pattern from wind data, but the same story prevails. Deaths are few and rare, they are well predicted by amber warnings (at about 22%) and better predicted by yellow warnings that the in the case of flood death (about 10%). This is largely due to there being fewer warnings, and their average severity being higher, but it is still illustrative of the context. The vast majority of days are safe from both wind and its casualties, but there were at least seven occasions when no warning was in place, but a risk to life form an extreme wind hazard materialised.

Assessing the method with a much smaller dataset for a more intense hazard type shows that largely similar conclusions can be drawn. Fatalities are very rare, where they do happen, amber warnings are a good indicator, yellow less so, and the warning system probably achieves a high degree of protection. A number of accidental deaths will always remain unaccounted for by the warning system, and their situational context will be of much greater importance.
Chapter 8  The Protective Effect of Warnings

8.4 Conclusion

The chapter addressed the final research question, by looking at alternative ways of considering UK flood vulnerability using the perspective of predictive warnings:

- Can definitions of vulnerability be applied to risk of death from weather hazards in the UK?

The analyses have shown that the hypothesis that flood and weather warnings are predictive, and therefore protective of the vulnerable (exposed) to severe weather and flood warnings is correct to an extent. Amber warnings, and the emergency systems they trigger, offer a good level of protection: we can guess at a high number of avoided casualties. At the same time, amber warnings prove to be reasonable predictors of casualties, probably because they reflect a significant severity of the event.

In the context of each case study fatality, it seems that different levels of warnings may have impacted, or failed to impact, risk taking decisions by victims. Simultaneously, we can assume that other affected people’s decisions not to take risks may have been taken in the context of active warnings. Although we have no method for assessing avoided deaths, the low numbers of casualties are suggestive of a strong degree of protection achieved by warnings and the institutional mechanisms which they mobilise.

With less than 5% of all warnings associated with any casualty, the UK may have reached a point of diminishing returns on investment in the accuracy and dissemination of warning systems, at least as far as risk to life is concerned. At the same time, the interpretation of warning severity may be more accurate in the Flood Guidance Statement system, than the NSWWS. Given the high number of yellow warnings which are associated with a flood casualty, and remembering from previous chapters that the vast majority of fatalities are accidental and a tragic result of circumstance and behaviour, the FGS definition of yellow level risk may be more appropriate. Events with a yellow level impact severity may pose risk to the lives of individuals, either contextually vulnerable and frail, or those who increase their own exposure to hazard through risky choices.
Overall, analysing severe weather warning does not generate a strong signal of trend or association through the casualty data. Behaviour and circumstance remains the best explanation for incidents of extreme weather death. Warning context add a theoretical dimension to this by asking – did the victim see a warning? Did they consciously disregard it? Were there systems in place for protection which were triggered by the warning? And, ultimately, does the death suggest that these systems were inadequate? Bringing evidence from all five analysis chapters together, we move on to a discussion of their mutual dependencies and likely conclusions.
Chapter 9 Who Dies, and Why Does It Matter?

If you look up the A865 on Google Earth, you will see a narrow ribbon of tarmac nervously stretching across a cloudy tumult of silt and sea. Built in 1982, the causeway linking up the islands of South Uist and Benbecula was one of several erected after the islands of the Outer Hebrides were brought under one local authority for the Western Isles.

The coast on the south side of the causeway is vast and exposed. The tide brings the Atlantic within a few hundred feet of the narrow lane that leads south west to the village of Iochdar. A small crofter’s cottage here was bought by the MacPherson family in 2003. At high tide the water could be a mere 60 feet away from the house; during storms strong gales would rattle the windows and bury the vegetable garden in sand. But Archie and Murdina MacPherson were Hebridean through and through; they returned to their home island after meeting in Glasgow. They wanted to raise their two children, Andrew and Hannah, breathing the same fresh salty air in which they themselves had grown up, living in remote safety, close to their large extended families spread out across the islands.

There is a piercing beauty in these vast flat windlands and the shallow pools and intermittent shingle that connects them, only to be blown and washed away, replaced by water. The landscape here is shifting, flowing. And coastal defences are not always sufficient.

In the evening of the 11th of January 2005 the north west of Scotland was battered by one of the worst Atlantic storms in living local memory, with winds reaching 100mph. Mobile phone lines were down, the power was out across much of the islands. The winds and the waves were bringing water inland, overtopping and flooding vast areas of the coast. On Benbecula a team of firefighters hit a flooded patch of road and drowned their engine. The five men abandoned their vehicle, linked arms and strode slowly through water three feet deep and rushing fast, past debris and flotsam. It took them some time to ascend a nearby hill and reach the closest house, crouching against the violent winds. They had a lucky escape.

At around 7pm, seeing the water rising towards their home, the MacPhersons and Murdina’s father, who had dropped by their house as he did every day, decided it was time to go. Archie’s parents lived a mile and a half away on higher ground, and this seemed like a safer plan than staying put in
the howling and banging of the winds. Two cars set out north east from lochdar towards the causeway, the grandfather in front, and the young family following close behind him.

The bodies of the four MacPhersons, aged 36, 37, seven, and five, and that of 67-year-old Calum Campbell were retrieved from the flooded crofts and inlets in different parts of the coast, one by one, over the three days following the storm.

South Uist was a community in shock. People had taken it to be “just another storm”, so common in these parts throughout the winter. There had not been any fatalities of this sort for as long as anyone recalled. Peter Ross, writing for *The Observer* five years after the tragedy (Ross, 2010), spoke to many local people who claim the island to have been changed that night. People became more nervous about leaving their homes, travelling between the islands at night, attendance at community events is down.

The tragedy-stricken Campbell and MacPherson families spent many years campaigning for a Fatal Accident Inquiry, which is the Scottish government’s equivalent of a coroner’s inquest. The local feeling is that the A865 causeway was to blame. Originally designed with three outlets, it was only built with one on its north end, due to a pressure to cut costs; something the Western Isles council has confirmed. The community sees the causeway as a dam, which increases flood risk during every storm and high tide by blocking the water.

On the night of the fatal storm, Archie MacPherson’s brother and nephew drove out towards the causeway to meet them. They turned back as soon as they saw it had flooded and tried to call their relatives and tell them not to cross. The house was already empty; but as far as we know, the water did not breach the cottage that night.

It wasn’t until 2017 that the families finally heard that there would be no inquiry. Two studies into the causes of the accident had taken a decade to complete. They advised flood protection measures on the causeway and potentially a replacement 250m bridge, which would cost £20 million to build. But no liability was assigned and an inquest was judged unnecessary as it would not yield new evidence. Many of Archie and Murdina’s relatives still live in the area, and cross the causeway daily, there is a new generation Campbells living in the crofter cottage, experiencing the joys of life on the edge of the world, along with the weather risks to which it is exposed.
The heart-breaking story of the MacPhersons is a poignant final case study for this thesis. It did not only capture the imagination of the UK in 2005, featuring in more than 50 articles found on LexisNexis®, but has continually been written about since (Ross, 2010; Martin, 2005; Ross, 2017).

Besides being a devastating local tragedy, the story had regional and national repercussions on the way we interpret fatalities from extreme weather. Deaths from floods, tidal surges, and storms are infinitesimally rare in the UK, but a shocking accident like this resonates through communities, the press, and policy for years to come.

We have mentioned several times that the difference between the UK and, for example, France in hazard fatality terms, is that the UK simply has not recently experienced, or is now sufficiently well protected, against the kind of sudden and destructive events that devastated Canvey Island in 1953, or the Lynmouth flood of 1954. Whereas in France, the flash floods of the Var and the Xynthia storm surge in 2010 claimed dozens of lives, the UK has not seen this level of impact since the 1950s. If multiple deaths from weather hazards are observed, they are from co-located victims, people walking or travelling together, and the MacPherson family are the most numerous example of a multiple fatality event for the entire study period. In fact, the incident demonstrates that this kind of impact is not beyond the realms of possibility for the UK and could happen again.

The study often came up against obstacles of definition in identifying the causal hazard of fatality. The South Uist incident is a good example of this. The family's cars were swept off the causeway by high waves and coastal flooding on the road, during a severe storm. The database actually categorises these fatalities as storm deaths. In keeping with other incidents in the list however, they could be interpreted as either storm or flood, seeing as the water was not where it should have been. This illustrates the complexities associated with many of the incidents. Especially at low numbers, we can see that the circumstances of each case study have a unique intersection of causalities, vulnerabilities, multiple hazard impacts, interweaving protection and warning structures. Most of the analysis undertaken as part of this thesis has been forced to simplify the multiplicity of the stories of individual tragedies in order to trace common threads, which often end up splitting anyway upon further investigation.
The victims of the South Uist storm span the age distribution curve from the young children to their retired grandfather. As passengers, the children did not have agency in the process, assigning them similar vulnerabilities to the adults in the situation. Physical strength could have been a factor as the family drowned, with the stronger adults able to withstand the waves for longer. But in reality average January sea temperatures off the coast of Scotland are about 8.5°C (World sea temperature.org, 2018), so it is almost certain that the cold shock and induced hyperventilation and asphyxiation killed the family before they has a chance to fight the waves. In this case, the risk was indiscriminate of vulnerability.

The geographical distribution of fatalities skews west even without considering this multiple fatality incident, which is the westernmost of all fatalities in the database. The UK’s most violent and rapid onset weather comes from North Atlantic weather systems; although they can be accurately forecast, their scale of impact may be less predictable, and in this case completely unforeseen. Besides the tragic loss of the family, the island suffered damages in the scale of £15 — £20 million, not accounting for losses sustained by crofters and home owners. In many aspects this was far from “just another storm”.

As a group, the MacPherson family represented both local knowledge, having grown up on the island and being accompanied by Calum Campbell who spent all his life there, and unfamiliarity of circumstance, having only moved back recently and not experienced a storm of similar intensity. From many case studies, we have observed that local knowledge, especially in the case of drivers, can often trigger a positive bias in risk perception. Knowledge of the terrain, a familiar ford, or a favourite shortcut feature in multiple stories of flood fatality. Knowledge empowers confidence and a feeling of security, which is enhanced further by the perception of the protective shell of a vehicle. We don’t know how the two cars came to be in the water, whether they were swept off by a wave, or if the drivers decided to drive into the flood on the causeway, or the lane leading up to it. This is all speculation, as we don’t even know where the cars were overtaken by the water. But we know that they chose the relative risk of their cars and the promisingly short journey over the relative risk of remaining in their waterfront home, which, as far as any of the articles fail to report the contrary, did not flood that night. So the excruciating fact is that had the family elected not to evacuate, they probably would not have died.
Amongst the fatalities in the database, evacuation is a rare activity at the time of death. Where destinations are reported, most drivers were actually heading towards home or simply out on more mundane commutes and errands despite the bad weather. The fact that evacuation deaths are rare suggests that evacuation, whether individual or instigated by the emergency services is usually a sound and safe choice. This brings us to the key finding of the study: the majority of flood fatalities where we know the circumstances of the death reflect people making decisions and taking steps in the face of hazard, which increase their exposure suddenly and dramatically. Often these risks taken are foolhardy: recreational water sports in swollen torrents, attempts to rescue dogs from rivers, efforts to unblock drains, culverts, and fix water supplies; the list continues. But the MacPherson case is different. The family actively tried to reduce their exposure by assessing their risk to life inside their house: they were travelling towards the safety of the family home on higher ground, taking protective action to the best of their understanding of the risks.

And it is this point which makes the South Uist tragedy the pinnacle of the reasoning behind this thesis. Studying the list of flood and severe weather fatalities identifies a number of weak trends, links, and indicators of risk, but this is not an exercise worthwhile in and of itself. The main finding is the confirmation that deaths from floods and extreme weather in the UK are rare. So rare, in fact that they fall far below the conventional level of risk which is used in health and safety practice as the threshold for action (1 death per year per million of the population). These deaths are, for lack of a more sensitive term, residual: accidental, barely predictable, and hence largely unprotected. But then once every few years an incident like the death of the MacPhersons is reported, which suddenly captures the imagination of the public, the local community and institutional structures. It is an emotional reaction, and a perception amplification of the real risk of hazard, but it is inevitable in a developed western economy. Our inherent value of human life, our political, legal, and human need to protect, makes accidents in the context of hazards an important issue, and an impact to be avoided at high, if not all costs. The following discursive sections will bring together findings from the five strands of results and interpret them in the context of natural hazard vulnerability theory, flood and disaster risk reduction policy, warning systems, and resilience perspectives.
9.1 What the findings bring to understandings of vulnerability in hazards research and policy

The headline finding of this study is that direct weather fatalities in the UK are rare, and have been rare since the major impact incidents of the 1950s.

![Graph showing number of extreme weather fatalities]

**Figure 9.1-1 Conceptual model of the reduction in fatality impact from weather hazards in the UK since the 1950s:**
There have been no weather events with a significant death toll in the same location since Canvey Island and Lynmouth in the 1950s (markers in the top left), although there have been storm surges of a similar magnitude to the North Sea surge since then. Some years, like 2007, represent an overall peak in fatalities, but this usually does not exceed 10 – 15 deaths. It is reasonable to speculate, that the dramatic reduction has been a result of the impact of policy, coastal defence, improvements in forecasting, warning dissemination, and flood response and protection measures.

The study of flood fatalities only covered the period 2000 – 2014, a quick survey of EM-DAT confirms that fatalities since Canvey Island and Lynmouth have been very few, even when events were severe. From the severe flash flood destruction of Boscastle in 2004, to the torturous month-long inundation of the Somerset Levels in 2014, the majority of significant events have passed without fatal incident, or with no more than one accidental death. The aftermath of Canvey Island saw major investment in the East Coast sea defences, which was followed by a significant programme of coastal and riverine flood protection over the remaining twentieth century.

After the events of the 1950s, there have been several junctures when a major event could be seen to have shifted the flood policy and investment priorities of the UK. The significant floods of 1998 and 2000 have been shown to be catalysts for changes in flood policy towards more risk-based
approaches (Johnson et al., 2005). But the floods of the late 1940s and early 1950s were far more devastating, especially at the human level. It could be suggested that a paradigm shift in policy after the destructive impact of the North Sea surge is a key factor in the subsequent low rate of mortality from flood and weather hazards.

There persists, however, a low but steady level of fatalities, identified by this investigation. The remaining – residual – deaths present a range of categories and complexities. The nature of these fatalities, just as much as the nature of the mass fatalities avoided, has implications for the understanding of risk and vulnerability, as well as for policy and practice.

9.1.1 A summary of the findings

To give context to the following discussion, it is worth briefly repeating the key findings of the five analytical chapters, which are most important for further exploration.

Chapter 4 Hazard Fatality Totals and Rates presented the main tallies of the database, which was built as part of this thesis project. It was found that for the period 2000 – 2014 a total of 225 people died from the direct impact of severe weather events; 62 of these died in flood events. Analysis of these deaths found no temporal trend during the period. A peak in 2007 was observed. Seasonally most weather event fatalities occurred from December to February, with an additional summer peak for flooding. The shape of the time series of total fatalities matched that which is available through EM-DAT, although the flood fatality database added substantial numbers of individual deaths not reported in the global database. Compared to the overall context of mortality in the UK, weather hazards and floods represented 0.09% and 0.02% respectively of all accidental deaths in the UK for the period, and 0.003% and 0.0008% of all deaths overall. Per million population risk of death from weather hazards was roughly $0.7 \times 10^{-6}$ per year for all hazards and $0.07 \times 10^{-6}$ for floods. This is comparable to fatality rates from all hazards in the US, but ten times less than US flood fatalities per million population. In risk management practice terms, this rate is far below the threshold of one death per year per million population, which is considered to be as low as reasonably practicable.

Chapter 5 Fatalities and Their Floods analysed flood death in the context of weather conditions at the time of death, assuming heavy rainfall to be the most likely precursor of surface water flooding. The analysis found that there were no deaths reported on days when there was no precipitation, and hence rain is a necessary condition for flood death. Half of the flood fatalities happened during
Chapter 9

Who Dies, and Why Does It Matter?

Extreme periods of regional scale rainfall, and half seem to have occurred during more localised and less extreme rainfall periods. There is a 5% chance of death when daily rainfall is 12mm or higher, although these events are very rare. Finally, over 98% of the most extreme rainfall events in the UK are not associated with a flood fatality at all.

Chapter 6 The Geography of Flood Death explored the geographical distribution of flood fatalities and identified a skew towards the west of the UK, which was evident, but not statistically significant. Elevation and terrain did not have any relationship with the distribution of fatalities. Rural and urban areas accounted for roughly equal numbers of flood death, and population density had an inverse relationship with death. This is important as population density should increase exposure, but in the case of flood death, more occurred in more remote and less populated areas. Overall, mapping flood fatalities showed that geography alone does not explain flood fatalities.

Chapter 7 Risk and Behaviour provided the greatest number of contextual and behavioural explanations for flood fatalities. Analysing the age of flood fatality victims showed that the elderly remain a vulnerable group for this hazard impact, especially in the context of deaths inside homes. Middle aged people (40 – 59) were also represented as a vulnerable group, which was a new finding. Children also appeared to be vulnerable because of their age, but the context of their vulnerability varied, with under-10s more likely to die passively, for example as passengers in cars, and teenagers more likely to die outdoors, participating in recreational water sports, for example. Gender was clearly associated with the likelihood of flood fatality at a 70:30 male to female split. The location of the victim was also a clear driver of fatality, and a way to explain the contextual factor. A small proportion of victims died indoors, mostly in their own homes. Old age was a deciding factor here, as well as the use of a flood pump, which caused at least three deaths from inhalation of fumes. About a third of victims died on the road, either as drivers or passengers of cars: important contextual factors for these deaths was the familiarity of the terrain, which increased their likelihood of driving into dangerous waters, and the motivation for driving, where reaching the perceived safety of home emerged as a risk factor. Most importantly, the majority of victims died outdoors, and in this group the gender ratio was even more strongly male skewed and the middle aged age group was at highest risk. Whilst some of these active outdoor deaths were associated with evacuation or mitigation of hazard impact (protecting a bridge, unblocking a drain, etc.), the majority reported
recreational outdoor pursuits, including walking and hiking, dog walking, and water sports. Although a spike in these deaths was observed in August, overall seasonality was not a major explanatory factor with many recreational activities at the time of death reported in the winter months. Despite all these observable trends, statistical significance could only be found for the positive relationship between age and dying in a flood. However, for other hazards, risk of death did not discriminate by old age.

Chapter 8 examined the warning context of each weather fatality. Over the period 2008 – 2014 just over half of the flood fatalities happened when an extreme weather warning was in place. Although we have no way of ascertaining whether the casualty was aware of the warning, we can speculate that protective measures were put in place triggered by such a warning. With a high False Alarm Rate for the prediction of risk to life, we can assume that Met Office severe weather warnings succeed in protecting lives when they were heeded. However, about a third of fatalities during the period did not match a severe weather or flood warning in their region, suggesting that fatalities can also occur when they are not expected or protected against. Overall, the findings were broadly similar to those for the rainfall analysis, indicating that warnings are accurate and verifiable, but not always protective of life.

9.1.2 Fatalities unexplained

The findings of the analytical chapters reject the null hypothesis that flood fatalities are predicted and predicated by vulnerability parameters and understandings of exposure. Whist we do find some fatalities from flooding and other hazards where we might expect them – a handful of elderly people drowning in their single storey homes – we encounter many more in circumstances where we wouldn’t ordinarily look. So we have a good understanding of what fatalities are not.

Fatalities are not fully explained by inherent exposure and the vulnerability it produces.

Neither population density, nor hazardous terrain and their associated exposure can explain all of the database’s flood fatalities. About 50% of flood fatalities occurred in urban contexts where exposure is increased through population density in the case of indiscriminate flood risk, and exacerbated by risk of poor drainage. The other 50% happened in remote rural areas where exposure is increased by proximity to watercourses and distance from structured protection services. Neither exposure parameter can explain a majority of fatalities.
**Fatalities are not explained by hazard magnitude.** The residual deaths which did occur all happened on days with some level of precipitation. However, roughly half took place when rainfall was extreme, and the other half happened in low intensity rainfall. The lower frequency of extreme rainfall does indicate its higher level of risk, but the occurrence of fatality in low event magnitude circumstances suggests again that this parameter is not a sufficient explanation on its own, and that risk at low magnitudes of hazard is insufficiently managed.

**Fatalities are not a representation of discriminating risk.** Vulnerability (age, immobility, or deprivation) does not explain the majority of fatalities in the database. Importantly, this finding is most likely a recognition of the impact of successful protection of the vulnerable. But it also shifts the focus of the vulnerability definition away from groups we expect to die in hazards, and towards new groups in which people enable their own vulnerability through choices and behaviours, in spite of their less vulnerable contexts.

**Fatalities are not a result of forecasting failures.** Severe weather forecasts have a reasonably high probability of detection for fatalities (0.6) and very severe amber and red forecasts are associated with such low numbers of deaths that they do seem to be protective against risks to life. The high rate of “false alarms” when an alert was not associated with a fatality, rather than phenomenon inducing warning fatigue, are indications of potential fatalities avoided, if and when they were heeded, and therefore a successful warning system which can reduce the degree of fatality, making the majority of severe weather events “harmless”.

### 9.1.3 What this study adds to scholarship

The flood and weather hazard fatality database developed for this PhD thesis is a unique comprehensive resource for the understanding mortality from flood and other extreme weather in the UK. No resource is available which identifies the number of fatalities reported and the level of detail and context for each death. The use of newspaper articles as a source of rich contextual information on case studies has not been applied to this type of data before for the UK. The database is a rich resource for case study and trend analysis of fatalities, which can inform both scholarship and policy.

Although the study is unable to attribute catchment size and response times to the watercourses where people died, it closely follows the work of Isabelle Ruin and colleagues about the Gard region.
floods in the South of France in 2002 (Ruin et al., 2008). By also using newspaper records and collecting data on the location and activity of the flood victims, this study applies a similar method to the analysis of casualties in the UK. In finding that most of the victims dies outdoors, the results echo those of Ruin et al., and the average age of fatalities calculated as 43 matches precisely across the two studies. A key finding in the Gard floods analysis is the relationship of catchment size and response time to fatality, which indicates that smaller catchments of around 10 km² were more dangerous than larger ones. The data available for this study could not be precisely matched to catchments, and therefore this risk-magnitude relationship cannot be confirmed for the UK.

By proving that old age is a factor of vulnerability to death from flooding, the study supports the rich body of research on contextual vulnerability of individuals (Coates, 1999; Ashley and Ashley, 2008; Cutter, 2001). However, by also identifying middle aged victims, specifically men, engaged in specific activities, as situationally vulnerable, the study enhances findings in more recent studies exploring the risk profiles of victims in developed economies with strong disaster risk reduction systems (Terti et al., 2016; Becker et al., 2015; S. N. Jonkman and Kelman, 2005). The findings of the study suggest that understandings of vulnerability in the context of weather hazards in the UK should incorporate more than contextual vulnerability factors. We should also consider dynamic vulnerability which changes based on the decisions victims make at the point of hazard onset, by consciously exposing themselves to risk. It seems that the strategy of protecting vulnerable lives and livelihoods has succeeded, with few of the deaths in the database presenting classically vulnerable indicators of age, deprivation, or limited mobility. The remaining fatalities represented people who increased their exposure to hazard through decisions and actions, actively increasing their own outcome vulnerabilities.

Whilst the number of fatal incidents is too low to draw specific conclusions, their contexts tell a variety of interesting stories. Contextual vulnerability, driven by age, gender, deprivation, and physical ability is at best partial, and at most insufficient in explaining weather deaths for the analysed dataset. Inherent factors play a role in predicting some vulnerability, but they are less significant than geography, location (indoor/outdoor/vehicle), or choice of activity. And ultimately, all fatalities can only be fully explained by a comprehensive assessment of the compounding set of context and circumstances. There is a strong argument for analysing the behaviours and risk
decisions of victims as the primary drivers of the risk to life amongst those fatalities that remain a problem in the UK.

The interaction, or even co-morbidity, of factors is the most enlightening method for analysing the fatalities dataset. Section 7.3.3.4 illustrated what happens, when we tentatively categorise the victims into vulnerable and not vulnerable, as well as active or passive in their pursuit of risk. Vulnerability was interpreted contextually, and assigned in cases where the victim was under 19, over 65, was reported to have limited mobility, or an element of social risk e.g. homelessness. Victims, who were not of a vulnerable age and were not reported to have any other classically vulnerable characteristics, were classified as not vulnerable. Victims who had been at home, asleep, or driving normally, i.e. not escaping, driving through flood water, or travelling as passengers were not classified as taking a risk. Victims who were outdoors, participating in recreational activities, helping, fixing, voluntarily evacuating or driving through water of indeterminable depth, were classified as risk takers.

Vulnerable people, defined primarily by their young or elderly age for the purposes of this analysis, represent less than a third of all deaths. This proportion should be analysed in the context of protection measures in place, which are aimed at vulnerable populations first. We do not have a measure for avoided fatality, but we can speculate that the relatively low number of older people in the sample is not only reflective of the general population distribution, but also a result of specific protection in place for these vulnerable groups.

Dividing up the sample in this way, shows that there are two fairly discrete groups of vulnerable people and risk takers, meaning that those who are judged to be vulnerable by a contextual definition, were for the most part not the same people who took a conscious risk when they died from flooding. The comorbidity of contextual vulnerability and exposure through behaviour represents about 14% of the sample.
Table 9.1-1 Comorbidity of vulnerability (age dependent) and risk taking behaviour in weather hazard victims 2000-2014: Vulnerable age groups identified as under 19 and over 65 years old. The vulnerable and risk taking age group were discrete apart from 14% of fatalities.

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Victim was of a vulnerable age?</td>
<td>27%</td>
<td>63%</td>
<td>10%</td>
</tr>
<tr>
<td>Victim took a risk?</td>
<td>63%</td>
<td>20%</td>
<td>17%</td>
</tr>
<tr>
<td>Vulnerable (by age) risk takers</td>
<td>14%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other risk takers</td>
<td>45%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The findings have clearly demonstrated that behaviour and risk taking is the main driver of the rare fatality occurrences. Co-morbidity of vulnerability and risk taking is especially evident in the elderly part of the dataset. Of the 35 fatalities where victims were over 65 years of age, 28 were active – either partaking in outdoor activities or driving. The passive and contextually vulnerable deaths, therefore are for the most part represented by younger children and a handful of elderly people inside their houses. The majority of elderly people in the database, for the most part, did not seem to perceive themselves as vulnerable. This begs the question of whether classic definitions of vulnerability remain relevant for the protection of the remainder of weather fatalities in the UK, or whether a new, behavioural definition is needed.

The co-morbidity of characteristic and behavioural vulnerability is a novel method of looking at flood hazard impacts in the UK. Ex-post analyses of event fatalities usually report age and gender of the victims, together with any other available contextual data, to analyse which groups were most vulnerable when a flood struck (Vinet et al., 2012; Ruin et al., 2008; Di Mauro and De Bruijn, 2012). Reviews of deaths from flooding and other hazards specify particular behaviours, such as driving through water of indeterminable depth, or voluntary evacuation decisions, which make the individual more vulnerable (Terti et al., 2015; S. N. Jonkman and Kelman, 2005). However, the integration of vulnerability (or lack of it) and risky behaviour has not been fully explored. Whilst gerontology literature has explored self-perception of age and ability, and its influence on lifestyle decisions (Grembowski et al., 1993), there is no literature linking this phenomenon with natural hazard impact.

There is substantial research into the social dimension of vulnerability and the social construction of risk, illustrated by the FLOODsite project, and specifically in the cross-country comparison of community perceptions of preparedness for flood impacts (Steinführer et al., 2009). This analysis of communities in three European river basins found that no specific social groups were more
vulnerable that others, but the level of social resilience varied depending on the context of the event and established measures. An integration of social and demographic vulnerabilities is found in the proposed by Social Flood Vulnerability Index (Tapsell et al., 2002), where vulnerable characteristics like old age and long-term sickness are considered alongside social features like a lack of home and car ownership, or weak support networks.

The behavioural dimension of risk has been widely explored in risk perception studies, both in its relationship with cultural theories of risk perception, and in analysing the heuristics which drive decisions about risk (Tversky and Kahneman, 1974; Slovic and Weber, 2002; Wildavsky and Dake, 1990). The impact of heuristic behaviour by a group likely to exhibit a cultural cognitive bias of reduced risk perception, can be traced in the number of flood fatality cases (77 for all hazards, 18 for floods) where middle aged men died in the pursuit of recreational and sporting activities. These activities were undertaken in clearly adverse conditions, often in familiar territory, and on several occasions with proficiency. Whereas driving choices and evacuation behaviour have been calculated and explored in depth by hazard mortality studies, the pursuit of normally low risk outdoor activities, such as walking the dog, for example, and the resulting exposure, do not feature in peer reviewed research. In fact, jumping into flood water to save a pet, which killed five people over the study period, is a perfect example of heuristics; the mental shortcuts which lead to dampened perceptions of risk. Dogs are strong swimmers, and are often capable of staying afloat for a long time. Many breeds have coats which are far more resistant to the effects of cold water than human skin. Although the pet may wash up further downstream and need to be found, there is a high likelihood of its survival. But the emotional affect calling upon the owner to rescue the pet drove several victims to jump into very cold and fast flowing water without full consideration of the risk.

Specifically focusing on low risk activities, which in hazardous weather become high risk, as a leading circumstance of flood death is a novel finding of this study. It is difficult to tell how much low level risk activity goes on in total when flood warnings are issued, but there is clear evidence from this analysis that the heightened risks associated with this are a significant factor of flood fatality.

There is a vast practice of weather warning analysis and verification and a strong body of literature to support it; weather alerts and severe impact warnings are a well analysed dataset (Hurford et al., 2012; Doswell et al., 1990; Gee, 2013; Demeritt, 2012). However, warning verification on an impact
parameter, rather than event occurrence, has not been done before for floods in the UK. By analysing the Probability of Detection and the False Alarm Rate for flood death by severe weather warnings, even for a short dataset, the thesis delivers a new analytical approach and a new assessment. The severe weather warning of rainfall in Chapter 8, and the rainfall event time series in Chapter 5 are of similar scales and shapes, matching a similar number of flood fatalities temporally and spatially. This suggests, in keeping with verification research, that the forecasts are largely accurate. The additional finding is that fatalities occur in both low intensity rainfall, and in the absence of weather alerts, as well as during yellow severe weather warnings which do not explicitly anticipate a risk to life.

9.1.3.1 Placing the study within vulnerability literature

Conceptually, the additive significance of this study can be summarised by its relevance to the behavioural dimensions of risk, exploring: (1) low risk circumstances that still lead to fatalities as exposure; (2) comorbidity of advanced age and low vulnerability perception as context; and, (4) shifting vulnerability profiles during hazard onset being the result of conscious risk taking decisions as the hazard impact modifier.

Returning to the discussion of literature from Chapter 2, we can build these into the development of hazard vulnerability theory by considering again the bodies of literature described in section Error! Reference source not found. and Chapter 7Error! Reference source not found., both of which can be seen to grow from early conceptualisations of hazard risk exposure by scholars influenced and working alongside Gilbert F White (1971).

Hazard and opportunity are two varied but possible outcomes of the interaction of natural disasters and human systems, which are mediated by a choices and characteristic of vulnerability, according to Burton, Kates and White in the early editions of the seminal Environment as Hazard (Burton et al., 1978). Two branches of literature grow from this, as summarised in Figure 9.1-3, seemingly parallel, but with clear opportunities for bridging the hazard and culture paradigms.
Figure 9.1-2: How this study bridges the gap between two bodies of literature: using the risk temporal frame of O’Brien’s model (2007) and building on Cannon’s (2008b) work to explain residual vulnerability as a consequence of choices.

Taking a temporal perspective of a risk unravelling, like O’Brien (2007), can be seen as an attempt to do this. Terry Cannon’s (2008b) culturally explained vulnerabilities, once other contextual factors have been rejected, is the clearest connection between cultural risk perception and context vulnerability. However, there is a missing link between these two threads, which explains the majority of the outdoor fatalities identified by this study. That link is the culturally determined behaviours and choices, taken at the time of the hazard unfolding, which modify the low level of contextual vulnerability of a victim. In this way, the current study brings the two literatures on cultural perceptions of risk and structural vulnerabilities together through the modifier of behaviour and a temporal frame.

More specifically, for the perception of vulnerability in disaster risk reduction literature, the findings on outdoor flood fatalities in the UK add an important point of vulnerability in the hazard timeline. Here we return to the temporal development of vulnerability first addressed by Figure 2.2-6 Error! Reference source not found., reproduced and adapted below reflecting vulnerability characteristics found in the corpus of UK extreme weather fatality reports.
Figure 9.1-3 Building a behavioural vulnerability step into the hazard timeframe: developing an earlier figure from Chapter 2, this demonstrates how the findings of this study build an extra step into ex ante and ex post perceptions of vulnerability, adding ex inter stage vulnerability analysis.

9.1.4 Why are few deaths still significant?

In their comparison of the impacts of storm Xynthia on the French Atlantic coast and the flash floods in the Var region of France, both in 2010, F. Vinet, D. Lumbroso and colleagues note a “surprising paradox”. Whereas at very low numbers of fatality, their epidemiological analysis and economic quantification is baseless and impossible, the protection of lives remains a policy priority, and an unacceptable impact in press and public perception (Vinet et al., 2012, pp.1181). Similarly to the UK, there is no centralised database of flood death in France, mostly because deaths are so rare as to be judged negligible, but also because the subject of death, especially through negligence of public bodies or the victims themselves, is taboo in public narrative. However, according to Vinet et al, the increasing frequency of disasters is driving up interest in ex-post disaster studies, which analyse the causes and context of fatality.

Vinet’s et al. analysis proceeds to expose a very causal and contextual nature of population vulnerability, with 71% of Xynthia’s victims older than 60, two thirds living in single storey homes which flooded during the night-time storm surge which, moreover, was not centrally alerted by
MétéoFrance. So in reality, Xynthia and its impacts do represent a “perfect storm” of inherent vulnerability, contextual exposure and systems failure. Thankfully, no such catastrophe has struck the UK in over sixty years.

But with even lower death tolls, the “surprising paradox” between risk theory, hazard prevention practice, and public perception also rings true for the UK. Defra’s Flood Incident Management Plan for the period 2015 – 2020 seems to acknowledge the priority of fatality avoidance in its very title “Saving Lives and Livelihoods” (Environment Agency, 2015). Although the rest of the document provides little in terms of steps to reduce risk to life specifically, one of its measures of success is “damage avoided and lives saved” (pp.22). Although the steps of the plan reduce a variety of risks, mortality included, and no specific steps for fatality avoidance are presented, the important of recognising fatal impacts as significant and important is clear in the language of this fundamental UK flood policy document.

Institutional awareness of risk to life is reflected in the definitions assigned to a range of severe weather and flood guidance warnings disseminated to emergency services and the media. The National Severe Weather Warning System communicates risk to life at the amber and red alert levels. The Flood Guidance Statement issued daily by the Flood Forecasting Centre to emergency responders, also identifies individual risk to life at yellow alert level, where vulnerable people, or those finding themselves in unfamiliar circumstances, are likely to be in mortal danger. Given the findings of the database, most incidents of fatality represent individual fatalities, where context of vulnerability. Unfamiliar or unpredictable circumstances intersected to create the fatality scenario. Although familiarity often served to amplify the risk of exposing behaviour, especially in the case of drivers taking familiar routes through flood water, overall, the interpretation of risk to life by the FGS level alert is in tune with empirical findings presented by this study.

### 9.1.5 What are the policy implications?

Ultimately, it is likely that the single most useful finding of this study, one which has implications for policy and practice of flood risk reduction and forecasting, is the low number of fatalities from flooding, as well as from other weather hazards in the UK for the study period 2000 – 2014. This finding has three main messages and implications.
Firstly, that the UK is a relatively safe place when it comes to risk to life from extreme weather; in fact, the level of fatality is below standard measures of risk as low as reasonably practicable (ALARP), below which there is not a lot of reason, or any statutory obligation to protect lives further. The study is a comprehensive and detailed evidence base for this conclusion, and could be used to justify halting further investment aimed specifically at protecting lives, rather than property, for example. This conclusion also raises questions about the priority given to risk to life in the latest Flood Incident Management plan (Environment Agency, 2015), and whether this reflects realistic perceptions of risk.

Secondly, the findings demonstrate that those levels of protection which are in place are successful at protecting vulnerable lives. People’s lives are well protected in their own homes; the elderly are not overrepresented amongst the victims; organised evacuations are successful; and no flood fatalities occurred in specific economically vulnerable circumstances. The intention of the Flood Incident Management Plan of “saving lives and livelihoods” is largely accomplished in the first part, and has been so for decades. This situation may change, however, if protection is withdrawn or if climate or population change drastically changes the impact profile of hazards. Therefore, current levels of protection are largely successful at preventing fatalities, especially among contextually vulnerable groups, and need to remain in force. But more of the same is unlikely to reduce mortality further, because the nature of those fatalities which do occur is different: they are residual fatalities, unexpected and un-forecast.

Which brings us to the third message of the low mortality conclusion. Those fatalities which do occur are unpredictable, accidental, and linked to a variety of outdoor circumstances. Protection focused on people in their home is unlikely to reduce them. The vulnerability paradigm identifying those at risk, is unlikely to capture most of these potential victims. Warnings are unlikely to reach them, and if they do their level could be misinterpreted. To identify, reach, and protect future potential casualties, disaster risk reduction structures need a new behavioural paradigm of vulnerability, and a targeted warnings system. In part, this finding is an endorsement of the formulated Flood Incident Management Plan 2015 – 2020:
"We recognise that often the greatest risk to people’s safety during flooding is when they are away from their home, and that people can be exposed to flood risk in many different locations at different times. Our service will ensure that all people at risk, wherever they are, will have access to information and warnings so that they are aware of their risk and can take appropriate action to protect their own safety." (Environment Agency, 2015, pp. 9.)

An evaluation of the propensity of warnings is hard to do, and any assumptions about avoided fatalities will be highly speculative. But an important implication is that both the database and the Environment Agency recognise the importance of reaching people on the move with warnings and information. With the majority of fatalities occurring outdoors, the findings of the database provide ample evidence for the relevance of this strategy. The Environment Agency disseminated flood alerts through Twitter push notifications in some areas of England and Wales, improving access to warnings on the move. However, the system implies an opt-in mechanism wherein individuals follow the alerts, and also does not differentiate regionally, meaning people on the move may receive alerts for irrelevant locations, potentially driving complacency towards these warnings. Most other warning services to individuals around the UK involve calls to a floodline or an online service i.e. implying proactive search for the alert from the user and therefore some level of awareness of the flood conditions. Targeted flood warnings currently only exist for assets under the Civil Contingencies Act and businesses wishing to pay for a targeted warning service. All these systems are based on a physical address of one or more properties, and cannot be used to mitigate against dynamic risk to people on the move.

The low number of flood fatalities, and deaths from other extreme weather hazards are residual but not negligible. A social contract exists wherein institutional structures direct resources towards protecting lives, even at below ALARP threshold risks. UK flood risk reduction practice demonstrates an awareness of both the importance of hazard fatality, and the fact that residual risk is concentrated outdoors and not always driven by classical definitions of vulnerability.

Theory, policy, and practice can further benefit from illustrative case studies of the type of activity, behaviour, and context which has led to these residual fatalities in recent years. The scope of these incidents is not a large enough sample and presents few statistically significant trends. However, awareness of the range of incidents, and the anecdotal intersection of multiple risk factors is illustrative; it can guide further research and practice towards particular pockets of activity at which reduction efforts could be focused.
9.2 Behaviour as the driver behind individual exposure

Having identified what fatalities are not in section 9.1.2, we can reject all the hypotheses which link fatalities by inherent vulnerabilities, geographical exposure, or hazard magnitude. Instead, we turn to the behavioural explanation, which must go back to the behavioural explanation, which provided a common background to the partial impact of all these factors.

Two thirds of the victims in the database faced a decision point upon encountering a hazard. “Should I dive in to rescue my dog?”, “Should I drive through water?”, or simply, “Should I leave the house today?” were among the final thoughts of the individuals represented in the database. It appears from the investigation of weather warnings, that this risky behaviour is only partially mediated by accurate forecasting. Although we do not have a measure for the number of deaths avoided by warnings, we see a persistent low level trickle of deaths from missed warnings.

The behavioural dimension fills a gap in the dominant vulnerability narrative of the natural hazard impact literature. Traditional concepts of context and outcome vulnerability, explored in Chapter 2 of this thesis fail when it comes to sudden onset, low to medium magnitude weather hazards in countries like the UK and US where there is a strong established disaster response system already protecting the majority of the contextually vulnerable. In most of the case studies captured by the fatalities database, context and outcome vulnerabilities of victims remain low and unaltered as the hazard strikes, yet a person dies. These fatalities are driven by behaviours and choices at the moment of hazard. This finding suggests that the vulnerability paradigm needs to reconsider criticisms of Burton, Kates and White’s behaviourally driven vulnerability as too individualistic (Burton et al., 1993). We observe that at the residual level, after protection of the contextually vulnerable, only the individualistic and behavioural causes of vulnerability remain.

Ex-post analyses of disasters in countries with high levels of protection have previously highlighted risk-seeking behaviour including recreational flood sports (Becker et al., 2015), the perils of driving through flood water (Terti et al., 2015), and erratic evacuation behaviour (Werritty et al., 2007). But in the study of UK flood fatalities, we see for the first time, systematic and comprehensive case study evidence, that supports the hypothesis that behaviours and choices are the main drivers of the remaining vulnerability. Burton, Kates, and White described the behavioural dimension of
vulnerability in early edition of *The Environment as Hazard* (1973), but since then contextual vulnerability has come to dominate the literature. However, the behavioural paradigm best explains the dynamic vulnerability of those who take a risk during a hazard onset through conscious active choice.

What we observe from a majority of the UK flood fatalities is an example of vulnerability dynamically changing as the hazard unfolds. Individuals go into the event with strong physical capacities, often equipped with the means of escape (vehicle) or protect themselves (proximity to home). However, they make a choice in the face of danger which dramatically changes their exposure, and the efficacy of their capacity to withstand impact; they go outside, travel far, partake in outdoor sports, follow dogs into dangerous torrents, attempt to fix damaged utilities without proper training. By choosing to do each of these things, the individual immediately becomes vulnerable in that particular context, even if they would not fall into the classically defined vulnerable groups.

These behavioural choices are sometimes surprising in their simplicity. Studies of disaster fatality in Australia often report incidents ranging from the dramatic to the farcical. Contexts have included heroic attempts to guard property during bush fires to foolhardy weather games, like flood surfing (Becker et al., 2015). In the UK, often the activities at the time of death were far from so inherently risky. There is a solid representation of fatalities during kayaking, canoeing, mountain climbing, and other adventurous outdoor pursuits. However, the vast majority of outdoor deaths are related to activities that are much lower risk in normal circumstances, but significantly increase exposure during hazard. No examples in the literature could be found that systematically consider low risk recreational activities, such as hill walking, hiking, dog walking, scenic walking; all of which feature dominantly in the present database as precursors of fatality when undertaken in hazardous weather conditions. But it is these undervalued circumstances which represent the known unknowns of hazard post mortems. The low risk activities, powered by cognitive biases towards feelings of safety, and by heuristics away from full consideration of the risks, are representative of fatal outcomes in low probability scenarios where they intersect with other risk factors. Within these intersections lies a potential key to identifying the most relevant fatality circumstances for action.
Chapter 9  Who Dies, and Why Does It Matter?

9.2.1 Intersections of factors 1: mobility and warning

Drivers and their passengers are a group at risk of making decisions which increase their exposure and render them vulnerable, according to the findings of the database. The perceived safety of a vehicle can encourage drivers to take risky decisions, such as driving through flood water. This effect is not mediated by knowledge or skill; in fact, it may be exacerbated by it. Over a third of drivers who died from the range of investigated weather hazards were professionals: lorry, cab, or delivery drivers. In these cases, their skill did not work to prevent them from driving in dangerous conditions, in fact it may have encouraged them to take the risk, with their confidence in their ability forming a positively biased perception of the risk.

Out of the flood deaths identified by the database, fatalities in vehicles were all explained by a temporally and regionally matching weather warning in place: drowning in cars was representative of warning “hits”, rather than “misses”. We have no way of knowing whether drivers received these warnings, but we can assume a partial dissemination propensity via radio, and potentially road signs.

What we do know is that the Environment Agency considers drivers a priority for risk awareness communication. In the winter of 2018 the Environment Agency joined efforts with the AA to embark on a campaign to warn drivers not to drive through flood water, called Floods Destroy (Environment Agency, 2018).

As part of the Floods Destroy campaign, the AA surveyed 14,000 members and found that roughly two thirds of drivers say that they would consciously take the risk and drive into flood water. Similarly to the wider findings of the study, the risk taking is higher amongst male drivers (71%), compared to female drivers (62%) although the difference is less stark that the male/female fatality ratio (70:30). Further reflecting the findings of the database, younger drivers, under 34 years old, were far less likely to enter flood waters than older and middle aged drivers. Crucially, in all regions, and across all age groups, where the survey was conducted, turning around to find a safer route was a minority position. Finally, AA records allow identifying locations of particular renown, where drivers often get into trouble in flood water. Apparently, Rufford Lane in Newark, Nottinghamshire saw over 100 rescues in five years (Environment Agency, 2018). The repeated appearance of particular “hot
spots” in records suggests that knowledge, shared experience, and warning are all insufficient deterrents for drivers who enter flood waters.

![Figure 9.2-1 Environment Agency campaign against driving through flood water:](https://squad.co/work/environment-agency/environment-agency-floods-destroy-aa-infographic/)

The Environment Agency views the survey results as a consequence of a lack of understanding of the risks, and the campaign is therefore designed to be an educational one, quantifying the risks in clear and tangible terms, starting with risks to life.

The interplay of the security and confidence biases instilled by driving, and the unheard or unheeded warnings, illustrate this stark risk profile scenario, which has already been picked up as a policy priority. The fatalities database reports 13 casualties, which could be explained by this bias.

### 9.2.1.1 Outside and west

The database as proven the pursuit of outdoor recreational activities as a risk factor during hazardous weather. 26 out of 62 fatalities could be explained by this type of activity. Similarly, we have established an observable, though not statistically significant, skew towards the west in the geographical distribution of fatalities. Looking at these two factors together reveals that the South West and North West regions of England, together with Wales account for 18 out of the 26
recreational activity cases. Wales alone accounts for eight. If fact, it is the outdoor deaths drive the majority of the westward skew.

These deaths included six dog rescue attempts, three canoeing accidents, an attempt at “pool plunging”, and a variety of scenic and recreational walks. Although the database is too short to capture signals of fatality hotspots, different stretches of the river Usk in Powys and the river Neet in Cornwall feature more than once in the database. Both are characterised by multiple scenic bankside routes.

It is hard to say how much recreational activity goes on in Wales and the western counties of England during periods of intense rainfall. Perhaps the overall climate of the region makes people less averse to enjoying the outdoors in poor conditions. Possibly, the intersection of variables is driven by the regions’ National Parks and multiple Areas of Outstanding Natural Beauty, which makes them popular “staycation” spots, hence the simple numbers of people exploring the outdoors in these regions can explain the statistically increased risk. Having said this, where the origin of the victim is reported, they usually die in their local area.

In any case, there is a powerful comorbidity of outdoor recreation and western regions, which probably implies a need for awareness raising, identification of the most dangerous catchments, and protections in place.

9.2.1.2 Multi-hazard intersection

One of the factors unexplored by the database is the intersection of mortality during periods of very poor weather that sees multiple hazard impacts. Grouping the database by date rather than hazards, can reveal a number of “perfect storms”. St Jude’s Day October 2013 was one such storm, counting four gale impact deaths and one storm wave casualty. The last days of January 2011 saw two flood deaths and one gale impact fatality in Wales and the West. Five people died in winds and floods during a week of bad weather August-September 2008. And the Atlantic weather system that caused the deaths of the MacPherson family on South Uist, also led to flooding in Carlisle and Bradford, and severe impact wind gusts in Cumbria.

The intersection of multiple hazards is a significant factor of risk increase. Firstly, it is indicative of more severe weather overall, and a greater intensity and spatial footprint of the events. Secondly,
it stretches the efforts of emergency responders thinly, meaning that fewer fatalities are avoided through rescue, signage, and evacuation.

There are multiple ways you can die in bad weather, and the wider the variety of impacts, the greater the likelihood of circumstances creating a fatality profile scenario. Arguably, it could be speculated that recreational outdoor activities are reduced during these events, because their footprint and intensity make them national level news, which possibly acts as more of a deterrent. However, the available data does not allow for evidence of this phenomenon.

Indirect impacts, however, could be seen as exacerbated my multiple hazard impact. The database identifies three flood deaths which resulted from inhalation of flood pump fumes. Other studies (Hampson and Stock, 2006) report similar incidents, not only for fuel pumps, but for diesel generators used when storms and other hazards lead to power cuts. Fumes inhalation deaths are common in Europe during the three day post disaster period (Iqbal et al., 2012). Multi hazard interactions, and their associated impacts on utilities, increase the risk of the improper use of pumps and generators, which can lead to CO poisoning and other fume inhalation fatalities.

In reality, however, multiple hazard events are much better suited to classical ex-post disaster impact analysis, in order to trace the various mechanisms of risk exacerbation, in the context of reduction measures in place. The fatalities database uses deaths as a unit of measure, rather than events, making this sort of analysis impossible with the collected data, which is one of several important limitations to this study.

### 9.3 Limitations of this study

Limitations pertaining to the analytical methodology of each of the five results chapters are discussed in their individual methodology sections. Therefore, this section will focus on the limitations of the underlying fatalities database. Although it has developed into a comprehensive and valuable tool, the database is limited by the data it collects and the assumptions it applies to them.
9.3.1 Definitions

Definitions of direct fatalities may have limited the results because a number of potentially countable deaths were rejected as out of scope. The strict definition of death as a direct weather death that is reported means that the estimates of mortality risk are minimum estimates. Taking account of indirect fatalities from road traffic accidents or lagging indirect impacts on health, may have generated different results. For example, if aquaplaning and third party collision fatal accidents were included, the age and skill profile of drivers may have been different, the number of road deaths would be significantly increased, and decision making would have been less of a factor in this part of the dataset. Although the reasons for rejecting these deaths as out of scope (they were not exclusively caused by hazard, and could have happened in other, less severe, conditions because they are mediated by driving skill) remain true, the example shows how sensitive the results could be to alternative definitions.

The same is true regarding the definition of weather hazard as a rapid onset convective event. If heatwave and cold wave impacts were included, the results would be starkly different in terms of numbers, indoor/outdoor splits, and vulnerability profiles. Again, the exclusive definition remains true due to the risk factor of pre-existing medical conditions, which drive the majority of heat and cold fatalities.

9.3.2 Scope and scale

Probably the most significant limitation for the study is the time period under analysis. A 15-year period, at such low frequencies of weather fatality makes it very hard to draw out trends and practically impossible to prove statistical significance. Stretching the period even slightly in either direction could bring in the multiple flood and storm fatalities of 1998 and the snow storm casualties of 2018. It should be noted that the LexisNexis® methodology would become less comprehensive in this case, as article numbers drop dramatically before 2000. The short time period allowed for an in-depth analysis of each case study to the extent that information was available in the reports. A casual survey of periodic fatality reports since the end of the study period shows that the overall nature of the incidents has not changed – deaths are rare, accidental, outdoors, and individual. Therefore, extending the scope would probably achieve statistical significance for some of the indicators, but would be unlikely to disprove the existing findings.
9.3.3 Binary interpretation of fatality

The data gathering process relied on a report of death as a binary indicator of a data point. Reports where people were missing or had been taken to hospital were disregarded unless they were followed up by a confirmation of death. This approach simplified data collection and interpretation, and reduced the uncertainty associated with each data point. However, it also limited the study in two ways. Firstly, there are likely to be some fatalities amongst the unconfirmed search and rescue, or deaths in hospital, and at the low frequencies of fatality, almost any number of additional data points could impact some of the trend analyses. Secondly, it prevents the study from being able to comment on rescue operations, deaths avoided, injuries and close calls, all of which would be interesting both in their risk profile, and in the probability of their detection by warning systems, which is assumed to be higher if emergency services were out in force and able to respond.

Commentary on the effectiveness of warning systems, and hence the response of emergency services is caveated in the study by the recognition that false alarms of fatality could well indicate protective warnings, and that the more severe weather warnings are more effective, through the assumption of avoided fatality. This is an important parameter for which the study cannot provide a measurement method, it is therefore limited in the commentary that can be drawn on the work of first responders and the difference between the risk and vulnerability profiles of those who died and those who were saved.

9.3.4 Inaccuracy and lack of location information for geocoding

A significant limitation of the data is the difficulty of assigning a precise location to a fatality. Newspaper reports are vague about location, usually reporting the closest urban centre, rather than the dangerous place along a river course. This is compounded by the fact that death is often reported at the point where the body was found, which leaves us only to speculate where the victim fell in the river. And in reality, more than half of the records have no location data at all besides a city or a region. This circumstance makes it impossible to draw insightful conclusions about the locations of fatalities. We cannot identify risky catchments or hazardous stretches of coast. The more remote the fatality, the worse its location reporting, making the dangerous outdoor rural activities even more hazardous as we do not know the precise location of the incident. With better location data, ideally by x y coordinates, a range of spatial analyses could uncover more interesting
trends: proximity to watercourses, proximity to home, risk zone differentiation, and a number of other angles could be taken with better location data.

9.3.5 Data quality
Following the initial data trawl and clean up, the quality of the flood fatalities data was significantly enhanced manually by looking at all of the relevant articles, rather than one reference article, and augmenting the information with further qualitative data from adjacent reports or targeted online searches for the incident. This allowed for the descriptive case studies presented throughout this thesis, and for a sanity check of analytical outcomes. The richness of the data improves understanding of likely circumstances significantly. The contextualised fatality data could also be used to overcome shortfalls in other parts of the analysis, for example the date match parameter in the warnings dataset could be adjusted by looking back at reference articles and judging whether there was a delay in reporting. However, this was a labour intensive process, and so it was not undertaken systematically for the entire fatalities database. This makes parts of the database (flood fatalities) more accurate than others.

Moreover, when examining warning data for the analysis in Chapter 8, there were some challenges in using the limited data available. Issues of consistency, duplication, format variability and the fact that warning data did not cover the full research time period all made their analysis somewhat limited.

Addressing the described limitations and increasing the scope of analysis is just one of the ways in which this research could be taken further.

9.4 Further research
The study identified a very low number of fatalities and analysed them from five different angles. Although the study covered only a 15-year period, the pattern of fatalities, or lack thereof, can be assumed to represent an overall trend for annual extreme weather fatalities the UK since 2015 and in the short to medium term. This is based on comparing fatalities to those identified in EM-DAT for a much longer time series, as presented in Figure 4.1-4. Since 1991, annual deaths from extreme weather events have been low, and while a sudden and extreme storm, like Burns’ Day Storm in
1990, could create a single multi-fatality event, the levels of protection in place are consistent with keeping deaths at low integer numbers every time. The repetitive pattern of circumstances that lend itself to the sorts of generalised analysis proposed in Chapter 7 year on year, allows some confidence in the results. It is likely that the extreme weather fatalities database can be updated to a similar level for subsequent years and beyond, especially for flood deaths.

Methodologically, this study has proven that newspaper records are a source of rich data on hazard fatality, that can be interpreted in close to epidemiological detail. Newspaper records on shocking impacts, such as fatalities, are abundant, with multiple reference building up a case study picture of many fatalities. The newspaper time series has historical scope and the rules of journalism ensure that reporting detail is similar across the years, building some consistency in available data. Specifically the details and characteristics of flood victims can allow for inference of behaviour, risk appetite and other qualitative characteristics, that are impossible to ascertain from other sources, like emergency services records. Importantly for research, there are fewer ethical implications connected with using this publicly available data on a sensitive subject such as death. Altogether, the experience of this study, supported by recent analyses from colleagues (Taylor et al., 2014; Escobar and Demeritt, 2014), suggests researchers can continue to use newspaper records for natural hazard impact research, and LexisNexis® as a platform for their interrogation.

However, there still remain avenues for further research which can shed more light on the nature of flood and extreme weather fatalities in the UK.

9.4.1 Deaths from gale impact

An exploratory analysis of deaths from the impact of severe gales and their warning contexts was completed as part of the discussion of Chapter 8 The Protective Effect of Warnings. At several points in the database the distinction between flood deaths and storm fatalities is tenuous, however gale impact fatalities have a discrete morphology, mostly describing death from blunt impact trauma caused by falling objects (trees, masonry) felled by severe winds. On a number of occasions, secondary fatalities describe deaths in explosions or from electrocution caused by falling trees.

Therefore, for this distinct category of hazard fatality, we can count more fatalities than for floods or storms – 81 deaths for the study period. This is taking into account that the news bias is likely to miss some wind deaths due to their even more random and individual nature than fatalities from
other hazards. So, while winds kill more people in potentially less predictable ways, the MetOffice and emergency services are comparatively more blasé about wind hazards.

Severe casualty inducing wind storms are much less frequent in the UK than extreme rainfall and floods, and some years reported just one or even no deaths at all from this form of hazard, while 2007 saw 15 gale impact fatalities, and there were 21 in 2002. Unlike the steady low rate “trickle” of flood fatalities, wind hazards have a very different temporal profile.

In forecasting terms, with fewer event and forecasts but more fatalities, the false alarm rate for death is significantly lower, while the probability of fatality detection is about the same as for floods. This means that fatal gale impacts are more dangerous and less predictable.

The list of wind fatalities in the database shows a much closer to normal age distribution and a greater number of women killed than in floods. Importantly, wind fatalities do have a deprivation parameter of vulnerability wherein deaths in caravans and mobile homes, which are less able to withstand the impact of falling trees, often represent lower income households, unless they are referring to holidaymakers.

Overall, the indications for wind events are that they have a much more classically “hazardous” risk profile than floods in the UK. Striking suddenly, killing indiscriminately and equally across age groups and locations, there is a seemingly greater level of chance associated with gale impact deaths, which is worth investigating.

**9.4.2 Multiple hazard analysis and future scenarios**

The UK is pretty well protected against current flood and other extreme hydro-meteorological phenomena. There are few fatalities, coastal defences and barriers usually hold out, and lives are protected by existing warning systems in place. However, the property damage and cost of flood impact is rising, and in terms of risk to life, complexities are introduced by the interaction of multiple meteorological impacts, while emergency services are stretched. The degree of protection and successful fatality prevention may well change with time and climate change impacts. Extreme events are foreseeable, but the UK’s response infrastructure had to deal with relatively few extensive life threatening events, with the exception of Boscastle in 2004. There is scope for
scenario modelling of extreme hazard impact and fatality risk outcomes in the context of climate change, demographic change, and changing risk and vulnerability profiles.

### 9.4.3 Case by case

The richness of qualitative data available for many of the fatality case studies suggests an alternative angle of analysis. Data from newspaper reports could be augmented by coroner reports to determine precise circumstances of death. With the right ethics considerations, invaluable qualitative information, as well as more precise location of death data, could be sought from local communities and even relatives, which could enable the development of a detailed behavioural profile for a casualty. The warning and weather context of each case could be established and judged likely to have been seen or not by the casualty. Narrative trend analysis could be used to develop a close risk profile of potential casualties, as well as the best way of communicating warnings to them. Given the circumstantial, contextual, and individual nature of flood fatalities, such a case by case approach could be an enlightening direction for further research.

### 9.5 Conclusion

The effort to assemble a database of UK flood fatalities for the period 2000 – 2014 has shown that deaths in flood waters are circumstance enabled accidents, a combination of an “act-of-god” hazard impacts and bad luck or poor choices delivering the levels of exposure.

It is not the classically vulnerable that die in UK floods. It is the active, outdoorsy risk taking middle aged man. His death cannot be explained by any of the tested parameters, leaving only one – behavioural parameter. If we want to prevent him from dying, perhaps we should look at situational vulnerability from his perspective, and consider how to adapt warning, response, navigational and communication systems to catch and warn him on the move.

Considering the findings of the study, we can conclude that:

1. The UK is safe, lives are protected from fatal hazard risk in the UK; on average, the UK is safer that other countries with similar levels of exposure and disaster preparedness.
2. Therefore, it could be suggested that the UK has reached a point of diminishing returns on investment in protection of individual lives above current levels, with the risk already reduced far below the threshold of so far as reasonably practicable.

3. Those groups defined as vulnerable by the classic vulnerability paradigm are represented amongst the fatalities, however, they are not the main driving force behind the data. In fact, their low rate can be used to assume that the protection of vulnerable individuals from risk to life is effective in the UK.

4. Most fatalities, however, are explained and driven by behaviour and the rapid choices that people make when they encounter a hazard.

5. Severe weather warnings and Flood Guidance Statements are verifiable and accurate systems, which still miss a low level of background fatality. In terms of interpretation and dissemination, warnings could be better at reaching people outdoors and on the move, and the definition of a yellow warning as posing individual risk to life in particular circumstances is probably needed.

Much of this is already recognised by active policy, including the Flood Incident Management Plan 2015 - 2020:

“We recognise that often the greatest risk to people’s safety during flooding is when they are away from their home, and that people can be exposed to flood risk in many different locations at different times. Our service will ensure that all people at risk, wherever they are, will have access to information and warnings so that they are aware of their risk and can take appropriate action to protect their own safety.”
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