Nat Hazards (2012) 61:1179–1201
DOI 10.1007/s11069-011-9975-5

ORIGINAL PAPER

A comparative analysis of the loss of life during two recent floods in France: the sea surge caused by the storm Xynthia and the flash flood in Var

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Received: 2 March 2011 / Accepted: 29 August 2011 / Published online: 18 September 2011

Abstract This paper aims to analyse and compare the loss of life that occurred during two recent floods in France. The first flood was due to a sea surge triggered by the storm called Xynthia that hit the Atlantic coast on 28 February 2010 (41 flood-related deaths). The second was a flash flood that struck the Var Department in the French Mediterranean region on 15 June 2010 (26 fatalities). After detailing the assumptions and expected outcomes of the study of disaster-related fatalities, the paper focuses on the characteristics of the victims and the circumstances of their deaths. In the first case, 71% of the victims were people aged over 60 (mainly women) who were surprised while they were sleeping and who died in or near their homes. In the case of the flash flood, the profiles of the victims were diverse as the flooding occurred in the afternoon and many people were trapped in open. The paper also highlights the factors that explain mortality. Physical factors such as water depth were determined. The relationship between the water depth and the age of victims was found to be relevant. In the case of the storm surge Xynthia, the correlation between age and water depth is positive. For the flash flood, the correlation between age and water depth was negative as male adults died in open. In the first case, the vulnerability of people was closely linked to human features such as type of housing and age that people are not directly responsible for. During flash floods, dangerous behaviour by people highlighted the role of risk-taking in loss of life. We also examined the particular case of the deaths of the children. The paper concludes by discussing the factors of

Electronic supplementary material The online version of this article (doi:10.1007/s11069-011-9975-5) contains supplementary material, which is available to authorized users.

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vulnerability on frail population such as elderly people or marginalized. The lack of risk awareness and crisis preparedness were clearly a major factor of vulnerability.

Keywords Human vulnerability · Flash flood · Storm surge · Flood-related fatalities · Prevention · Dikes

1 Introduction

In recent years, there has been an increase in the impact of disasters. This has resulted from a combination of extreme natural phenomena and the exposure of vulnerable populations. As a result, it has become more important to analyse the human impact of disasters (World Bank 2010). However, we often lack the data to quantify the human vulnerability. It is often difficult to answer questions such as "What is a vulnerable population?" and "Who is a vulnerable person?" The assumptions are often made that elderly people and children are the most vulnerable to floods, without necessarily having any data to support this. Although global databases (such as the Dartmouth flood observatory[1] and the EM-DAT CRED database[2]) provide some general information on the background to fatalities in recent flood events, there are few studies available that provide a detailed analysis of the conditions of death and the "profile" of people killed or injured during floods. Vulnerability should not be reduced to the "susceptibility to die" and can assume many other aspects; however, we think that the analysis of fatalities can help to improve our understanding of the drivers of human vulnerability. This study is based on the analysis of fatalities that occurred during two recent floods in France. The first event was caused by the storm called Xynthia that struck Western Europe on 28 February 2010. It resulted in 47 deaths in France, of which 41 were due to coastal flooding as a result of a sea surge on the French Atlantic coast. The second event was the flash flood that occurred in the Var Department in southern France on 15 June 2010. It has been estimated that 26 people died as a result of this flood. This paper commences with brief details of the characteristics of these floods. The second part of the paper focuses on the assessment of the conditions that led to the fatalities. The third part discusses the outcomes of this analysis and how the results can be used to enhance flood mitigation measures.

2 Key-questions and assumptions concerning the analysis of flood-related deaths

Disasters often mask individual tragedies. If an interest in this subject appears "morbid" or even "indecent", it seems to us that we can learn fundamental lessons to help to reduce the impact of future disasters.

At an international level, different databases collect and make available figures on disasters and their consequences. The International Disaster Database EM-DAT is the most well known (Hoyois and Guha-Sapir 2005). It collates a number of parameters for each disaster including the number of deaths, estimated cost of the damage and the number people affected. The number of fatalities is particularly high in Southern and Eastern Europe. For France, the CRED database lists 38 floods since the late 1970s. The major

[1] http://www.dartmouth.edu/~floods/.

[2] http://www.emdat.be/ (the international disaster database of centre for research on the epidemiology of disasters).

floods that France has suffered from are listed in Table 1. However, the exact location of the victims and nature of the disaster in the database are often not clearly stated. In developing countries, the large number of flood deaths that have occurred discourages any attempt at detailed post-disaster analysis. In developed countries, the number of death is often perceived to be too low to be "significant". It has been recognized that the mortality rate due to disasters has decreased in developed countries since the beginning of the twentieth century (Pielke 2000). For example, disaster-related casualty data in the United States attest to this decrease (Henson 2001: 244). However, since 1975, the annual number of flood-related deaths has remained at around 100 per year. This poses the question as to whether improvements in flood prevention related to the improvement of forecasting and relief have been "hidden" by an increase in exposure (i.e. an increase in construction in the flood zone). Hurricane Katrina with a death toll of 1,464 deaths (Jonkman et al. 2009) showed that deadly disasters do not exclusively affect poor countries. It should be noted that federal authorities in the USA did not provide any accurate and definitive overview of the death toll caused by Katrina (Jonkman et al. 2009). This explains the renewed interest for the retrospective assessment of disasters through the collection and analysis of the death toll (Ahern et al. 2005). We have chosen to assess and explain the vulnerability of people at risk through an analysis of the fatalities that took place as a result of two flood events in France.

In France, there is no centralized and detailed database for the victims of floods (Boissier and Vinet 2009). Why is this case? It can be explained as follows:

- Death is a taboo subject that is difficult to address especially in many countries (Flores and Smith 2010)
- The number of deaths is considered to be low or negligible
- Deaths are considered as unavoidable because in developed countries they form an "incompressible tribute" on which it is impossible or at least difficult to act. These arguments appear in the Ph.D thesis of Torterotot (1993, 49) which is still the reference study for flood-related damage in France.

Deaths due to flooding often appear as a residual risk, possibly because they cannot be quantified economically. Its epidemiological study would not deserve attention. This is a surprising paradox. State and local actors promote the protection of people as a priority, as the death of a person is considered as unacceptable by the media and the population.

In France, as in many countries, causes of death and measures to reduce vulnerability of persons are based on empirical knowledge that is not capitalized. Assumptions concerning the vulnerability of people facing natural hazards are made by analogy. Older people are vulnerable in general, so hence they tend to be vulnerable when they face natural hazards. It is the same for children or any category of vulnerable persons, hence the phrase "women and children first"! Many studies reported the high degree of vulnerability of young and elderly people (French et al. 1983; Mooney 1983; Coates 1999; Ashley and Ashley 2008) but there are some discrepancies between the kind of flood and the circumstances of death.

The other issue is the division of responsibilities among the services in charge of the safety of people. In France, the Ministry of Interior (Police) is in charge of the relief and crisis management together with the Departmental Firemen services (SDIS). However, the prevention of floods is the responsibility of Ministère de l'Ecologie, du Développement Durable, des Transports et du Logement (MEDDTL) and epidemiological studies and the possible aftermaths of disasters related to people's health is the responsibility of the Ministry of Health and regional health agencies. This partly explains the low number of research studies on disaster-related deaths in France (Antoine et al. 2001; Wilson 2006). In

Table 1 Recent floods in France that have resulted in deaths

Date of floods		Places affected	Regions	Number of deaths	Estimated damage (€ million)
Start of the event	End of the event				
01/03/1983	01/05/1983	Nord-Pas-de-Calais	Northern France	10	Unknown
14/07/1987	14/07/1987	Grand Bornand (Haute-Savoie)	Alps	23	Unknown
03/10/1988	03/10/1988	Nîmes (Gard)	Mediterranean regions	11	500
22/09/1992	22/09/1992	Vaison-la-Romaine (Vaucluse)	Mediterranean region	47	250
01/09/1993	01/11/1993	Camargue	Mediterranean region	10	310
01/12/1993	01/01/1994	Camargue	Mediterranean region	10	260
17/01/1995	31/01/1995	Basse-Normandie	Northern France	15	400
12/11/1999	14/11/1999	Aude	Mediterranean region	35	530
08/09/2002	12/09/2002	Gard	Mediterranean region	24	1,200
28/02/2010	02/03/2010	Vendée, Charente-Maritime	Atlantic coast (Xynthia)	41[a]	4,230[b]
15/06/2010	16/06/2010	Var	Mediterranean region	26	1,000–1,500

Source MEDDTL (Ministère de l'Ecologie, du Développement Durable, des Transports et du Logement), CRED (EM-DAT: The OFDA/CRED International Disaster Database—www.emdat.be—Université Catholique de Louvain—Brussels—Belgium), CCR (caisse centrale de réassurance)

[a] flood-related deaths only

[b] damage due to flood and wind

France, the Anena (national association of investigations on snow and avalanches) has set up the only database on victims of natural hazards in France. This database is updated via the collection of an information sheet that is filled out every time an avalanche results in a casualty. Some information is available in the public domain and other information remains confidential (http://www.anena.org). However, while there are multiple databases, indicators of all kinds, there is neither a census nor analysis of flood-related deaths in France.

In this paper, we postulate that deaths are not "casual". They both reflect the exposure to hazards in addition to the high vulnerability of the victims. In the case of flooding, the vulnerability can be measured through the physical capability of the person themselves, i.e. their ability to resist water velocity and low temperatures. This capacity is linked to the age and the health of the person. Moreover, the availability of protection and/or shelters also determines vulnerability. The vulnerability of buildings is increasingly referred to as a factor of human failure. It is defined as both their propensity to damage and its ability to protect the occupants by the presence of a storey or roof evacuation for example (Kelman 2007). Finally, a more "active" vulnerability matches dangerous behaviour, both conscious and unconscious (Wilson 2006; Ruin 2007) including car traffic. The works of many authors (Gruntfest and Handmer 2001; Ruin and Lutoff 2004) show how risk-taking behaviour can influence the definition of human vulnerability.

Safety advice is often based on empirical knowledge and the experience of people or services (e.g. authorities and insurers) in charge of prevention or crisis management (firemen), but this knowledge is not capitalized. As a consequence, preventative measures or warning instructions are not based on an accurate epidemiology of disaster-related deaths. Should people stay put or evacuate? Do people die in their home, in their cars or rescuing other peoples? Are there an "irreducible" number of fatalities owing to carelessness or is "carelessness" a euphemism to hide a high level of vulnerability?

The study of the victims is still reserved to French medical epidemiology (Six et al. 2008), and interdisciplinary research should be developed in particular to link the profile of victims and the circumstances of death with prevention and crisis management (Tapsell et al. 2002).

3 Two different flood events

Although it has been stated that the human death toll from floods has been reducing in developed countries, two deadly floods that affected France within 3 months in 2010 have changed people's and the media's opinion. The floods were totally different. The first event was caused by the Xynthia windstorm on 28 February 2010. The storm itself was rather casual in its features but it generated a huge sea surge in the Departements of Vendée and Charente-maritime on the Atlantic coast. The second event occurred on 15 June 2010 in the Var region when flash floods hit this area. The date of this event is unusual as recent Mediterranean heavy rain used to fall in autumn (e.g. floods in the Gard in September 2002: 23 deaths and Aude in November 1999: 35 deaths, see Table 1). Before studying in detail the human consequences of these two events, we will describe the background to the two disasters.

3.1 Xynthia: the sea surge

The storm called Xynthia resulted in the deaths of 47 people including 41 related to coastal flooding. This death toll was the largest ever recorded for this type of event in France

(Garnier 2010). Xynthia appeared in the centre of the Atlantic Ocean at the latitude of the Tropic of Cancer and then shifted to the north-west following an atypical trajectory. The depression was observed in the south of the Bay of Biscay on Saturday, 27 February at 18:00. The centre of the depression passed over the Loire-Atlantique department on Sunday at 14:00 in the afternoon. The pressure was at its minimum (969 hPa). On the southern flank of the depression, i.e. on the coast of Vendée and Charente, average wind speeds reached 110–120 km/h, while maximum instantaneous wind speeds were registered around 160 km/h. These high wind speeds are not exceptional and they were largely exceeded in storm Martin that occurred on 27 December 1999 and which remains the "reference storm" for western France. Wind gusts had exceeded 200 km/h (Baleste et al. 2001). It should be noted that storm was forecast accurately by Météo-France the French weather forecasting service. Four departments had been highlighted as having a "red vigilance" by Saturday afternoon. However, the sea surge generated by the storm was not included in the alert message of Météo-France and it surprised everyone. According to the BRGM[3] who carried out a post-analysis of the storm surge (BRGM 2010), the sea was 1.5 m above the expected tide level on the shores of the departments of Vendée and Charente-Maritime. It coincided with a high tide (coefficient 102). In la Faute-sur-Mer, the worst hit zone, in the mouth of the Le Lay River, sea level reached 4.7 m NGF (i.e. 4.7 m above average sea level). As a result in many places and especially in the municipality of la Faute-sur-Mer where 29 people died, dikes were overtopped. It should be noted that the precipitation was very low. The observed water depths did not exceed 10–20 mm per day, and flows in rivers adjacent to the coast were not high. Thus, the sea surge was not exacerbated by fluvial flooding. This means that if the configuration of events that resulted in the coastal flooding during Xynthia was singular, then it is not so exceptional and it could reoccur with a combination of higher wind speeds, a higher tidal coefficient and fluvial floods as pointed out in various reports that analysed the event (MEDDTL 2010a).

3.2 Flash floods in the Var

On 15 June 2010, intense rainfall hit the Var Departement in southern France resulting in 27 fatalities. Meteo-France placed 11 departments in southern France on an "orange vigilance". The rain lasted from 7:00 on 15 June to 1:00 on 16 June 2010. Mesoscale convective systems discharged an excessive amount of rainfall (Artigue et al. 2010). In the area of Draguignan, from mid-day 400 mm rain fell within 9 h with intensities over 100 mm/h in some places. Such water depths (which were equal to half of annual precipitations) had never been observed since measurements commenced in Provence-Alpes-Côte-d'Azur region (Artigue et al. 2010). These large rain totals associated with high intensities triggered a rapid rise in water in small catchments. The river basin of the Nartuby River was overwhelmed, and the Nartuby River flooded the low areas of the towns of Draguignan, Trans-en-Provence, Le Muy and la Motte from 15.30. Later during the night, the lower plains of the River Argens were flooded affecting campsites and tourist resorts. These rivers were not monitored by the *Service de Prevision des Crues* (SPC, i.e. national flood warning service). Two months after, on 18 August 2010, French state services approved the extension of the responsibilities of the SPC to the rivers affected by these floods. This kind of catastrophic flooding remains relatively rare. Nevertheless, it is not an isolated case. According to historical evidence, the last flood that the event of June 2010 can be compared with was the flood of 6 July 1827.

[3] Bureau des recherches géologiques et minières, i.e. the national geological service in France.

4 Methods used to assess the nature of the fatalities

4.1 Availability of data on flood-related deaths

In total, the Xynthia floods and Var flash floods resulted in 73 fatalities (Fig. 1). There were 67 people who died as a result of flooding and only six people died from direct or indirect wind effects. In this paper, we have concentrated our attention on the survey of flood-related deaths. We first must point out the contrast between the focus of the media on the victims and the silence from the authorities on this question. The list of victims with the names of the people and their age, which is generally accurate, was published in the newspaper Ouest-France. The names of the victims were publicly named in the Cathedral of Luçon on the 4 March 2010 during a requiem. For la Faute-sur-Mer, these lists served as the basis of our research. In the Var Department, the names of the victims were listed in the Notre-Dame-du-Peuple Church in Draguignan where visitors were invited to come and pray for the dead. However, no global and definitive list of fatalities with the places and circumstances of death have been published by authorities. As a consequence, we led a field survey to collect this information. The statements of the fire services of the Vendée and Charente departments were very useful, and we used a form to gather information

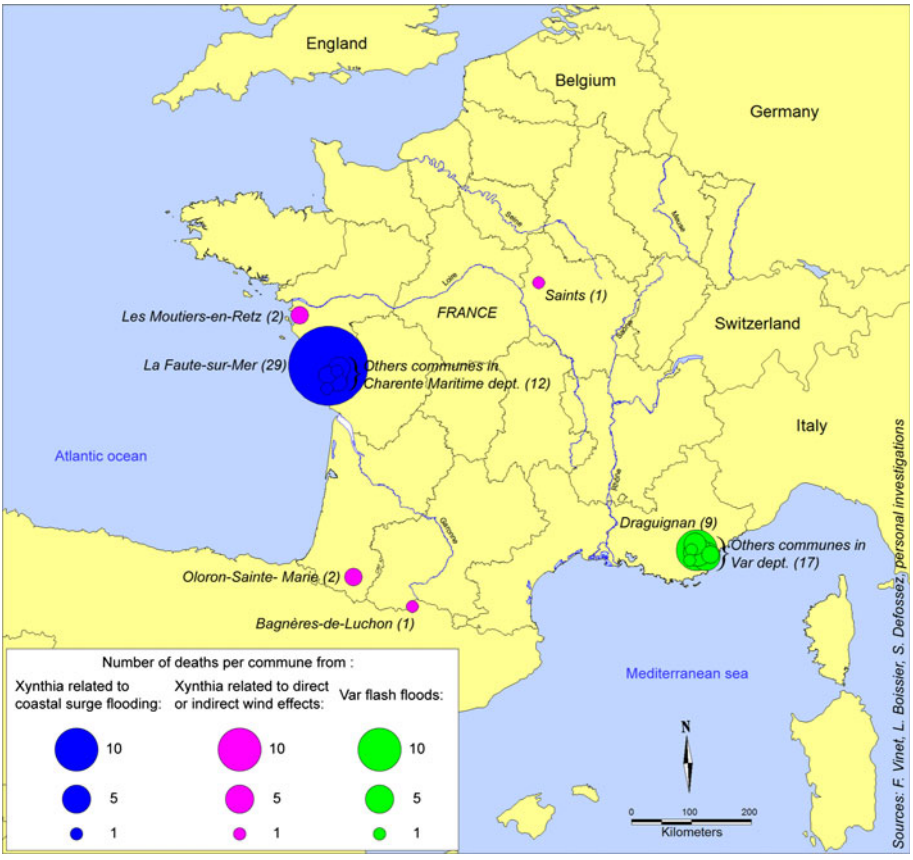

Fig. 1 Location of the fatalities during both the Var and Xynthia events

about each fatality including age of people, gender and water depth at the places of death. Fire services also proved to be a good source of information for describing the circumstances of death. The final dataset on fatalities (especially the location of death) has been built and verified in collaboration with the fire services.

In the Var department, rumours disseminated through the internet indicated that some people thought that the death toll had been underestimated by authorities for various political reasons. A so-called theory of conspiracy often appears after major disasters as in Nîmes where 10 years after the 1988 floods, 32% of the inhabitants still doubted the official death toll of victims and 20% did not believe it (Domergue et al. 1998). The lack of transparency on the number of victims and the lack of published definitive death tolls lead to people mistrusting the authorities. Legal cases that arise as a result of these events can also be an obstacle to the dissemination of the data. In Vendée, the Préfet (head of state services) asked his services not to disseminate any information or data on Xynthia storm before juridical proceedings had come to a close.

4.2 Data available on the fatalities

In Charente-Maritime and Vendée (Fig. 2), the number of deaths related to coastal surge flooding was 41, of which 29 occurred in the commune of la Faute-sur-Mer in Vendée and 12 in the department of Charente-Maritime. All victims have been identified and their place of death geo-referenced with a horizontal accuracy of 20–50 m. The commune of la Faute-sur-Mer represents a sample that has been submitted to a detailed analysis owing to the fact that 28 out of 29 fatalities were found in a 30-ha area called the "bowl of death" in the newspapers and by the political authorities. In Charente-Maritime, 12 victims were scattered throughout six communes making less relevant a fine-scale mapping.

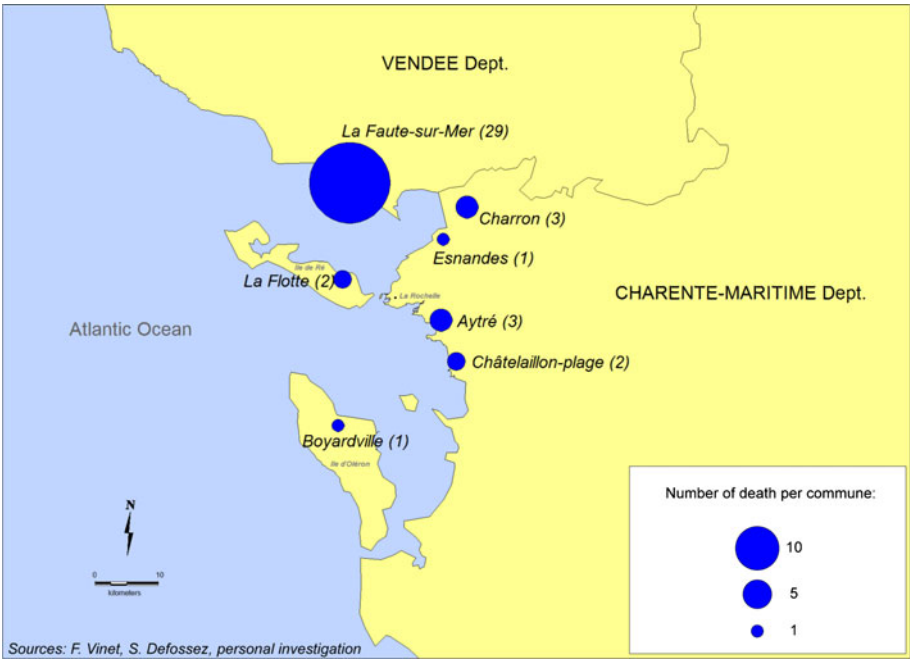

Fig. 2 Location of fatalities related to the storm Xynthia

In the Var Department, 26 victims were registered in seven communes. The locations of 22 deaths were geo-referenced with a horizontal accuracy of ±10 m. The places of death were more difficult to identify because the flooding took place during the day and many deaths were related to vehicles. The highest number of deaths occurred in the municipality of Draguignan with 10 fatalities, followed by Trans-en-Provence and Roquebrune with five deaths each. Saint-Hermentaire, a residential district in the village of Draguignan, was heavily hit with four fatalities concentrated in the same area of three neighbouring buildings including a nursing home.

5 The characteristics of the victims

5.1 Age and gender

For both events, the age of the victims was high. More than two-thirds (68%) of victims were aged over 60 (Fig. 3). For the Xynthia event, this rate goes up to 75%. The median age of the dead people was 75, which is very high even taking into account that the median age of the communes where fatalities occurred is 52 and that the French median age is 38 years old.[4] In the commune of la Faute-sur-Mer, people aged over 74 comprise only 15.8% of the population but we do not have statistical data on the "non-resident population". However, for the commune of la Faute-sur-Mer, we were able to determine from the land registry dataset that 20 out of 29 deceased persons were in their main residence. The storm Xynthia occurred during the February holidays. It should be noted that five fatalities were related to children on holiday in the main or second home of their parents or grandparents. No young adults (aged 15–42) died during Xynthia and only two during the Var event.

These figures corroborate previous studies on sea surge flooding mortality data. For the 1953 sea surge in England, studies (Jonkman 2007, quoting Kelman) show an over-representation of elderly people aged over 60 (72%). In relation to this, elderly women appear particularly vulnerable especially for Xynthia event for which women over 60 made up 44% of the victims. The case of child victims is a particular case that is examined later in this paper. We also examine this in the study of the relationship between age and water depth (see below).

In the Var, 11 women and 16 men died which confirms previous findings on the gender distribution of flood-related fatalities (French et al. 1983; Coates 1999; Jonkman and Kelman 2005; Ashley and Ashley 2008). Although low samples do not allow definitive conclusions to be drawn, this over-representation can be explained by a higher exposure of men in deaths related to car traffic and a tendency to take more risk (Coates 1999; Ruin 2007). According to the testimonies of rescue services, two kinds of profile of victim appear. The elderly people were found dead in night wear. This leads to the assumption that they were not able to withstand water and neither did they have time to react. People aged from 20 to 60 were found wearing night clothing mixed with clothes to protect against rain such as raincoats or boots. This suggests that these people were able to resist the water and attempted to rescue other more vulnerable people or tried to escape.[5]

[4] Source: INSEE: Institut national de la statistique et des études économiques.

[5] According to the testimonies of Dr Fradin and Dr Boisdin from medical rescue service during Xynthia event.

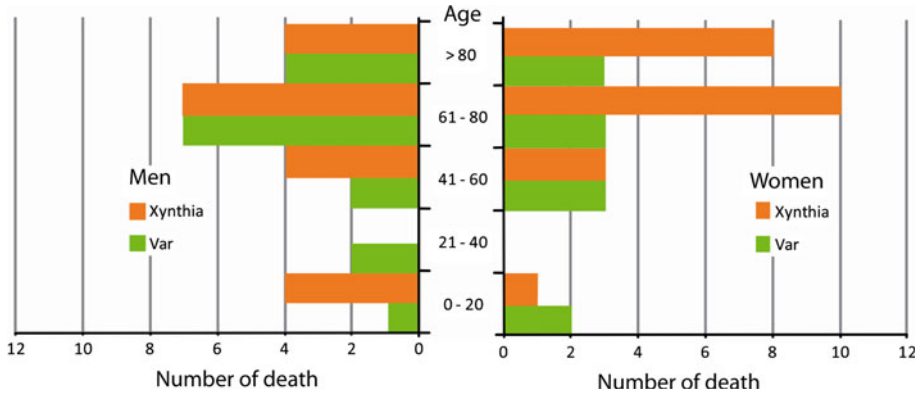

Fig. 3 Age and gender of the people that died during Xynthia and Var event (flood-related deaths only)

5.2 The origin of people

It is assumed that local people or people who have lived for a long time in the same place have a better awareness of risk than people who are not resident in the area (Hubert and De Vanssay 2005). For Xynthia, 27 out of 41 victims were permanent residents. Other people were staying in their second home for a visit during the holidays. During the flash flood in the Var Departement, only four people out of the 26 were not living permanently in the Departement which proves that not only tourist and foreign population are vulnerable. It is difficult to draw any definitive conclusions about the real awareness of the danger by the affected people. It is important to note that low awareness of the danger is not the prerogative of non-resident populations. Ruin (2007) goes further showing that despite a better awareness of the risk, local populations do not often pay attention to safety advice and still leave themselves exposed significantly to hazards.

6 The circumstances of death

6.1 Medical causes of death and physical vulnerability of the people

We have little information on the clinical causes of deaths. It was reported that two children died of hypothermia, but there are no detailed statistics. In the absence of systematic autopsies of the bodies, it is difficult to obtain more information on the direct causes of death except to suppose that drowning was the main cause without excluding heart attack for example. The hospital emergency services of la Roche-Sur-Yon (Vendée) found an relevant increase in the number of Takotsubo syndrome, over-represented stress cardiomyopathy stress over-represented in post-disaster phases (Sato et al. 2006). Of the six cases of (non-fatal) myocardial infarction treated following the storm Xynthia, three Takotsubo cases were identified while the average prevalence of this type of cardiomyopathy in coronary infarction is 0.7%.[6]

[6] Information collected from courtesy of Dr Fradin (La Roche-sur-Yon hospital).

Table 2 Type of dwelling and fatalities during both events

Kind of dwelling	Single-storey house	House with a shelter room upstairs	House with upper storey	Ground floor flats	Vulnerable dwellings (mobile home, caravan)	Sub-floor spaces	Unknown	Total
Number of deaths Var event	5	1	0	1	1	2	2	12
Number of deaths Xynthia (sea surge only)	32	4	1	2	1	0	1	41
Total	37	5	1	3	2	2	3	53

We have obtained information from social services (ADMR[7]) responsible for caring for the elderly in La Faute-sur-Mer on the vulnerability of people in the commune. Indeed, this service is very close to people, and every day a member of ADMR is expected to visit the people. On Sunday morning 28 February, the ADMR employee responsible for assisting elderly persons was unable to reach the patients' homes owing to the flooding. She was able to indicate to firemen the houses where people could be in danger because they were vulnerable. Local social services are a good source of information to identify and qualify the vulnerability of people and they should be included in the preparation flood emergency management plans. Finally, old age is undoubtedly a factor of vulnerability for people surprised by flooding at home. During the Var flash floods, figures confirmed this because seven of the 13 victims who died in their house were aged over 80 years.

Rather than concentrate on medical causes, we have worked on the circumstances and places of death. Deaths were located with a suitable horizontal accuracy and geo-referenced in a GIS dataset. These locations were compiled through a search for information about the circumstances of death through an analysis of media (e.g. newspapers and TV reports) testimonies of affected population and interviews with rescue services (e.g. firemen).

6.2 Fatalities and type of dwelling

For the Xynthia event, 32 of 41 people died in one-storey houses (i.e. bungalows). This shows that housing is a factor in vulnerability (Table 2). The sea surge occurred at night, and many people were surprised sleeping in their home. For the Var flash flood event, 13 out of 27 deaths took place at home but only four in single-storey houses.

It is not the objective of this paper to detail the vulnerability of buildings to flooding. However, on the Atlantic coast of France, the growth in the construction of single-storey houses is a result of the real estate growth and because it fits the local demand. The cost of land and real estate, the presence of elderly people and the decreasing size of households has meant that 80% of houses built since 2000 are one-storey houses. Moreover, the local urban planning rules discourage the building of houses with upper storeys. For aesthetic reasons, the communal Land Use Plan prohibits house over 6 m high and local standard designs must conform to strict rules: the elevation of houses above a certain level is prohibited as well the construction of sub-floor spaces such as cellars. In addition, very few

[7] Aide à domicile en milieu rural i.e. social services for elderly people.

Fig. 4 In La Faute-sur-Mer, people were obliged to break the ceiling to evacuate the house. (photo: F. Vinet)

Fig. 5 In La Faute-sur-Mer, rescue services gained access inside the house by lifting roof tiles. (photo: F. Vinet)

homes had roof openings allowing people to access to the roof and allowing rescue services to enter the home. Some evacuees had to break the ceiling to get out of their home (Fig. 4), and firemen were forced to lift tiles to access victims (Fig. 5).

The difficulties faced during the event of accessing houses were not helped by electric shutters that are fitted to many homes, which turned houses into traps when the electricity was cut off as the result of the flooding.

As a consequence, deaths linked to a drowning in absence of roof evacuation are not incidental. They reveal vulnerability or inappropriate behaviour. The presence of a storey is not synonymous with security as nine people died in houses with a second floor. It is important to note that in the case of windstorms, the occupants often prefer to sleep on the ground floor because upper storeys are noisy and considered as unsafe owing to the wind.

6.3 The circumstances of death in the Var

During the coastal flooding that occurred at night caused by windstorm Xynthia, the vulnerability of buildings in flood risk were critical factors in explaining mortality. In the

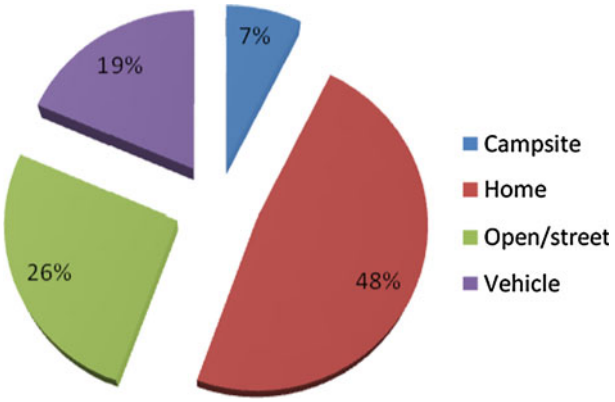

Fig. 6 The circumstances of death during flash flood in the Var on 15 June 2010

Var, when the flooding occurred in the afternoon, places and circumstances of death were more varied (Fig. 6).

Even though almost half of fatalities were located at home (Table 2 above), the other half of deaths took place in the open in the following circumstances: pedestrians on the street (26%), campsites (7%) or related to vehicles (19%). These deaths corresponded to very different situations that are difficult to classify. For example, a person endangered himself by rescuing his pet, and another people died from a heart attack in a campsite. In fact, more than the places of death, the circumstances of occurrence of death reflect the vulnerability of people. Indeed, the location of death sometimes masks dangerous behaviour. For example, two people died after attempting to remove their car from a basement garage. The situations are too numerous to list here; however, a common point characterized by them is that they often reveal "risk-taking type of behaviour" (Wilson 2006) or an underestimation of the danger that is faced by people in floodwater (Ruin and Lutoff 2004). In a survey we carried out on fatalities related to flash floods in the French Mediterranean region since 1988, it is common to find deaths following actions to save animals, to save personal assets, to cross bridges or ford rivers in spate although the danger seems "obvious" (Boissier and Vinet 2009).

6.4 The role of the dike failure

On the Atlantic coast, 37 out of 41 victims were living in areas separated from the sea by seawalls or dikes. The problem of dike failure was aggravated by the poor condition of the defences and the lack of maintenance is clearly pointed out in numerous reports following the event (MEDDTL 2010a: 41; Sénat 2010: 31; Slomp 2010). The distance between the place of death and the dyke was an average of 158 m. All the victims (except three in the commune of Charron) died less than 400 m from the dikes. However, in la Faute-sur-Mer, out of five people who died in two-storey houses, four were located less than 50 m from the dikes and three of them were directly behind the defences. The overtopping of dikes was the cause of their failure and the people living behind them were surprised by high velocities and the quick onset of the waters, so they did not have time to shelter on the first floor. In Charente-Maritime, two people who died in a one-storey house were less than 30 m from the dikes. Two others living 150 m from dike died on the ground floor, although

they had an upper floor; however, according to some reports, their health was not good. In Esnandes, a man living in a caravan 100 m from the seawall was suddenly flooded.

Unprotected coastal areas are not heavily urbanized. This explains why only three fatalities were recorded in these areas. The dike is therefore part of the "risk factor" when "protected" areas are heavily urbanized (Parker 1995).

6.5 Death and water depths

The water depth and velocity are considered to be the main factors in flood-related fatalities. Studies linking water depth to mortality are numerous (Jonkman and Penning-Rowsell 2008). If mortality is explained largely by the water depth, other factors fit into a more complex causal system. For the Xynthia event, flooding occurred at night and few witnesses noted the water depth. A reconstruction of the flood maps showing water depths was carried out using information from various sources. A map has been drawn by the State Services in Vendée (commune of La Faute-sur-Mer). The map considers the elevation of water over the natural ground. As a consequence, we completed it by collecting flood depths for each fatality when possible taking into account the water level inside the house. Water depths have been confirmed by firemen's reports. The water depth considered was the maximum level reached during the flooding. We are not able to reconstitute the level at the time of death. The maximum height was therefore retained assuming that death could occur before.

Figure 7 shows the distribution of deaths as a function of the maximum water depths at the place of death. Information is available for 58 out of 68 recorded deaths for both events. In Charente and Vendée, where all the deaths occurred at home, fatalities arose when water level was greater than 1.1 m. More than half of people died with water levels below 1.8 m. Several television reports confirmed that some people saved their life because the water stopped just below their chin.

In the Var (Fig. 7b), deaths occurred for depths as low as 50 cm. Six people died in less than one metre of water. High velocity was an obvious aggravating factor and not only in the course of rivers but also in relation to urban runoff.

We also addressed the relationship between the age and the water depth. If we include the children in the sample, the correlation is not statistically significant in both cases ($r < 0.25$ is not significant at $p = 0.05$). The case of children is a special one. They do not follow a correlation between age and water depth. We can explain this because young people may die from other reasons (e.g. hypothermia) but we have not got any accurate information on this point, only some testimonies from local residents. The second reason is that the children are dependent on their parents for their location and their security. For example, in the Var, a child was found dead in a place where 3 m of water had been recorded as a maximum. If the child was alone, we can suppose that he died before the water level reached 3 m. If he was with his parents, the lethal water depth depends on the resistance of the parents not on the child himself. That is why we excluded the children from the study of relationship age/water depth.

If we exclude the children, there is a slight but significant relationship between age and water depth (Fig. 7). For the Xynthia event (Fig. 7a), the people who died in the lowest levels of water were the oldest but we cannot explain the absence of old people dying in deeper waters. What determines the inverse slope is that adults and young-olds (65–74) did not drown in water depths under 1.5 m but the lack of older people dying in deep waters (>2 m) is supposed to be accidental. During the flash flood in the Var, there was an inverse correlation between age and water depth (r is significant at $p = 0.05$). Most young people and adults died in the open where they were exposed to high velocities. In homes, where

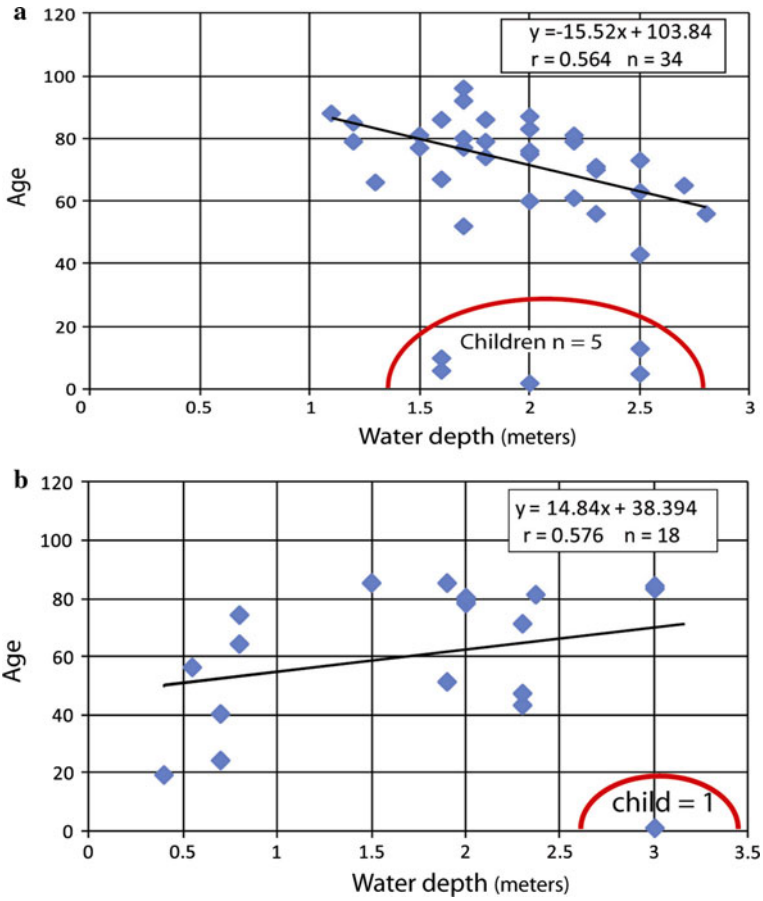

Fig. 7 **a** Relationship between age and water depth during Xynthia event. **b** Relationship between age and water depth during Var flash floods

elderly people died, in the majority of cases, the velocity was not the main factor in the cause of death. We also can explain the weakness of the correlation by the fact that we used the maximum depth level instead of water depth at the moment of death (which is more difficult to assess).

6.6 Death and water velocity

It is difficult to collect data on water velocities. During the Xynthia event, velocities were high because many deaths occurred in areas behind the flood defences. However, 80% of deaths were identified in closed houses. Disabled occupants found in their beds may have died of hypothermia or heart attacks before the water reached its maximum level. When people are trapped in a building, the velocity is not an important factor while speed of onset becomes decisive for assessing the danger. Jonkman (2007), adopted and synthesized Slager's studies, shows that when the stream is strong, the correlation between mortality and water depth is significant. However, for static flooding, the correlation is low owing to the number of factors relating to vulnerability: type of housing, age and dissemination of

alerts. We think that the more relevant data to measure the danger and explain mortality in remaining zones is the speed of onset.

The speed of onset of a flood is an important parameter in determining the number of fatalities. The speed of onset is particularly important for flash floods and cases where flood defences fail. Studies have shown that few deaths from drowning occur during slow rising floods (Few et al. 2004). It is important that parameters such as the speed of onset of the flood wave are mapped to assist stakeholders such as local residents, firemen and the police understand the most dangerous areas especially behind flood defences. In the Netherlands, the speed of onset of the flood wave is now incorporated into a "hazard rating" on some flood maps used for emergency and development planning (De Bruijn and Klijn 2009).

7 The building of a local vulnerable territory

7.1 Vulnerability factors relating to fatalities

We have assumed, similar to Kelman (2004), that vulnerability factors play as a big part in the explanation of fatalities as hazard parameters. The comparative analysis highlights some common factors of vulnerability such as age and health. The different factors of vulnerability appear in different contexts and certain spatial configurations, i.e. disaster scenarios. In the case of a coastal surge on the Atlantic coast, in addition to the hazard parameters such as the height of water, we have identified four major vulnerability factors:

- Age: the most vulnerable are elderly people as well as young children exposed to hypothermia owing to their small size and sometimes their inability to swim
- Type of housing: one-storey houses without a shelter area
- The sealing of houses: no possibility to escape by the roof and people trapped by electric shutters
- The proximity of dikes: by increasing the speed of the water onset, they reduce the reaction time.

For the flash floods of Var, we must add factors linked with vehicles and rescue initiatives by the victims.

In both cases, older people are over-represented in the deceased persons. The relationship between hazard parameters and age does not explain the mortality as a whole. The mortality of people facing disasters is far from being a mere function of age (Fernandez et al. 2002). Marshall and Mathews (2010) recall that "risk and vulnerability are rooted in identifiable economic and age-related disadvantages". Fernandez et al. (2002: 68) add that "Age does not make a person vulnerable. Rather it is the correlation between advancing age and the likelihood of having special needs that increases frailty". Behind "physical" vulnerability, we must argue with other social and psycho-sociological factors of vulnerability to explain such a toll.

7.2 Human and social vulnerability: the case of elderly people

As said before, we obtained from the services of ADMR some information on the vulnerability of the people and especially older and disable people. Out of 29 who died in la Faute-sur-Mer, at least six were particularly vulnerable because of age or disability. Two of them were bedridden at home. It is important to remember that 12 of the 41 victims on the Atlantic coast were more 80 years old. Local social services assistance is valuable to

Table 3 Classification of died people (people found at home only)

Place	Alone[a]	Couple[b] (couple dead together)	Couple (only one member died)	Family (>2 persons)	Unknown	Total
Xynthia event (Commune of La Faute-sur-Mer)	5	14	3	6	1	29
Xynthia event (Charente)	5	4	0	3	0	12
Var event	3	4	2	3	0	12
Total	13	22	5	12	1	53

Source personal inquiries of authors

[a] Read as: People living alone in the house when flooding

[b] Couple: 2 members of a family: husband and wife, father and son…

identify frail persons, and they are a source of interesting information and an essential partner for the drawing of local emergency plans (Marshall and Mathews 2010: 83). The mortality of elderly people is linked to their physical weakness and their isolation (Keller 2010), but in this case, one cannot state that the elderly were abandoned by social services. Indeed, people were followed by social workers (ADMR) and France has considerably strengthened the supervision of the elderly after the heat wave of 2003.

We also tried to identify the number of people who were lonely or accompanied at the moment of the flood. Table 3 displays the distribution of the people who died at home, i.e. 53 people (out of 67 for both events as a whole). The survey only takes into account the people who were found dead at home.

This example would show that being in couple is not a chance for escaping to death or being rescued by one's spouse. Approximately 51% of those who died in the home were in couple at the moment of the death. Testimonies collected after both events said that some people witnessed the death of their wife, child or husband "without being able to do anything" while the home was getting flooded. We can point out the large number of people (22) who died "in pair"; meanwhile, there were five couples, of whom only one member died. Beyond these findings, psychological processes may interfere such as the wish to die as a couple for the elderly people. Does the death of one's wife or one's husband lead to the abandonment of the struggle by the other spouse? At this stage, we can only point out this particularity; further explorations would be necessary to answer definitely.

In general, the health and ability of older people are the main criteria to explain their behaviour but we also must point out the lack of awareness. Carroll et al. (2009) show that in case of flood, many elderly die as a result of not knowing what to do, hesitating in their behaviour without having good reflexes. Ruin (2007: 220) stated that elderly people feel secure in their home and do not want to abandon their belongings.

Another problem is nursing homes. Some studies confirm that it is difficult to evacuate nursing home (Dosa et al. 2007). The majority of elderly aged 80 and over suffered from disability or chronicle disease. However, this issue would deserve more attention. According to the health and social services of the Var department, some premature deaths occurred after the evacuation of several nursing homes during the flash flood on 15 June 2010. But there has not been any epidemiological monitoring of this mortality till now.

7.3 Human and social vulnerability: frail non-elderly people

In the sample of dead people, we found people that fitted the profile of marginalized people. In Charente-Maritime, a man died in his caravan. In the Var Region, a 9-month-old child died on a campsite. Informal housing, i.e. the proliferation of light and/or fragile dwellings (e.g. mobile home and caravan), is another factor of vulnerability to take into account in the assessment of future vulnerability of coastal areas. A study of French state services (Mission Littorale 2005) shows that more and more people are living in fragile shelters (e.g. caravan, mobile homes, tents and old vehicles). This kind of housing is particularly common near the coasts (e.g. the Atlantic coast) and in the southern part of France (e.g. the Var departement) where the climate is milder. Those people are attracted by the economic activity generated by tourism; however, they cannot afford to rent a house as prices are one of the highest of the country. Moreover, campsites are more and more frequently occupied all along the year including in flood-prone zones.

The problem of frail people had already been pointed out for a prior climatic event in France. Keller (2010) produced a survey on the death of marginalized people who were buried in the common part of the cemetery as their bodies were not claimed by anyone. He demonstrates that although the great part of victims of the heat wave in 2003 in France were elderly people, a significant part of the fatalities concerns marginalized people sometimes young such as alcoholics, heroin addicted, tramps, migrants or people suffering from mental illnesses. Thus, the question of marginalized people is an issue to address for disaster prevention and preparedness.

7.4 A global vulnerability due to the lack of preparedness and information

Numerous research studies (e.g. Carroll et al. 2009; Perry 1997) have dealt with the response of elderly people to warnings but, in the case of the Xynthia sea surge, there were no evacuation orders, warnings or advice on how to handle the flooding. Thus, we consider that the main factor of the vulnerability of the population was the lack of information on flood risk and the lack of preparedness to face natural hazards.

Three indicators put together in Table 4 show that preparedness was insufficient in both regions at the level of State authorities, local government and local communities. State services and local authorities in charge with informing the population and preparing them to face a disaster had not accomplished the minimum legal requirements in terms of disaster preparedness and information. In both hit regions, only 26 communes out of 98 had a PPR (*plan de prévention des risques*, i.e. Prevention of Predictable Natural Hazards

Table 4 Flood prevention, crisis preparedness and information in the two flooded areas at the day of the disaster

	Land-use control document			Local emergency management plan	Information on risks at local level
	PPR approved	PPR planned	No PPR	PCS	DICRIM
Atlantic coast (44 coastal communes)	19	5	20	0	0
Var (54 communes)	7	6	41	No data available	9

Sources base GASPAR; Préfecture de Charente-Maritime; Préfecture de Vendée; MEDDTL, 2010

Plan), which is the main tool to control land use as regarding natural hazards (Pottier et al. 2005). Moreover, of the communes where a PPR was determining land use, the document has generally been approved in 2002 or 2004, which was too late to stop the urbanization growth. This document is drawn by the State services and implemented by the communes. The delay in the implementation of the PPR shows that the State was not aware of the importance of controlling land occupation in coastal areas.

With regard to crisis management preparedness, on the Atlantic coast, no commune hold a PCS (*plan communal de sauvegarde*, i.e. local emergency management plan), which is the official document drawn by local authorities to plan for emergencies. Nevertheless, some municipalities gave orders to evacuate some flood-prone zones but it was too late. In the Var, the post-event report ordered by the French government (MEDDTL 2010b) noted that the communes that set a *Plan communal de sauvegarde* developed this emergency plan from the perspective of forest fires instead of flood. The plans did not include "a census of the means of rescue and assistance, neither shelter places in case of flooding". Moreover, "the lack of relationship between the communes has prohibited any information exchange from upstream to downstream, information that would have been very useful to anticipate things better".

In addition, the response of the population was not appropriate as no information was given on their risk exposure. The DICRIM[8] is the official document to inform citizens on the risks that exist in the commune. It is written by local authorities taking into account the information given by the State services. This document was not adopted in any commune on the Atlantic coast. In the Var department, only nine communes (out of 54 communes hit by the 15 June event) had got a DICRIM but in a "light" version.

Post-event reports have shown the problem of evacuation (Assemblée Nationale 2010: 109–110; MEDDTL 2010a: 20). Usually, during windstorm, the safety advice is to stay at home. This seems to be in contradiction with an evacuation. The evacuation of inhabitants can be effective if carried out sufficiently early. It also depends on the conditions during the evacuation. Météo-France forecast the storm Xynthia well in advance and four departments were on red vigilance as early as Saturday night. However, although Météo-France was able to warn of strong wind, the forecasting of coastal flooding is not part of its core competencies or responsibilities. Moreover, an evacuation at night, during the weekend, in windy and rainy conditions would certainly be all the more difficult to set up as people to evacuate were aged and sometimes suffered from disabilities (Dosa et al. 2007).

It could be possible sometimes to evacuate the inhabitants to local shelters. Such evacuation strategies exist in other countries (e.g. United States and Bangladesh) in a different context that it is not possible to develop here. The evacuation of threatened populations is not largely practised in France. Moreover, the latest event that the Atlantic coast experienced was the windstorm Martin on the 27 December 1999. The wind-related damages were large but there had not been any significant damage due to sea surge. Even if improvements have been made in the forecasting and the warning of windstorms, it would be interesting to test the dissemination of the forecast tracks of windstorms, showing the potentially affected areas and mapping "cones of uncertainty" as is already carried out for hurricanes in the USA.[9]

Owing to the 1999 previous storm event, the local population and local authorities were aware and prepared to face windstorms. The safety advice was generally to stay at home

[8] DICRIM: document d'information communal sur les risques majeurs.

[9] http://www.nhc.noaa.gov/.

and to close all the openings of the dwellings. France is not trained to evacuate thousands of people, and massive evacuation is not a current behaviour anchored in people's minds.

7.5 At the roots of vulnerability, the lack of risk awareness and memory of the catastrophes

We cannot state that there was no knowledge of the marine surge in the region. The Atlantic French coast has repeatedly faced with the phenomenon of marine flooding during the last centuries (Garnier 2010). During the last century, three events similar to Xynthia have been identified: 9 January 1924, 16 November 1940 and 17 February 1957. There are two sources of knowledge: the vernacular knowledge and knowledge provided by the State services. Vernacular knowledge of marine submersions (locally called "vimers") has been demonstrated by historians (Garnier 2010; Sauzeau 2011). People living in daily connection with the sea (e.g. fishermen, oyster-farmers) were used to scrutinize the "sea's moods". Garnier (2010: 24) proves that formerly villages used to ring the tocsin (alarm bell) when a sea surge was threatening. This collective vernacular knowledge of danger has been lost with the arrival of new populations (i.e. tourists or pensioners) who are coming from other regions. Those populations are in contact with the sea only in summer when waters are quiet and "inoffensive". Elderly migrants are mainly coming from the western France and the region of Paris. They generally buy a house to live as pensioners in the coastal region they knew as tourists before. Their level of income is rather low (former employees or low middle-class). It explains partly why the majority of the dwellings are small and single-storey houses.

To compensate for this loss of contact with the sea, the State services have developed a more scientific approach of sea-related risks. A study had already warned of the danger of marine flooding and the poor condition of the sea defences (Raison 2008). Moreover, State services are drawing maps of marine flooding hazard along the Atlantic coasts. But these data collection is not achieved yet and, in any way, is too concentrated on the knowledge of the hazard. In France, the knowledge of risk is too often confounded with the mere knowledge of hazard (Ledoux 2006; Vinet 2010). Several interviews were led with members of emergency services and services in charge with flood prevention. They show that there was not a clear representation of what could be a huge sea surge scenario. Between the knowledge of the risk by some experts and a collective mental representation of the disaster, shared by all the responsible and the population, there is a gap to fill in order to enhance the preparedness of the population. Therefore, to enhance a real awareness and to favour emergency planning, it is necessary to build a collective mental representation of the disaster through an accurate description of expected impacts of the disasters. "Community leaders' awareness" and "land use planning in an era of deregulation" are the two first priorities to address in disaster reduction policies (Gruntfest and Handmer 2001: 320).

8 Conclusion

Behind the individual tragedies that the disasters reveal, the accurate analysis of fatalities after catastrophes provides valuable information to qualify the vulnerability of a population and to assess the effectiveness of prevention measures. The profile of the victims and the circumstances of death suggest that in most cases, flood-related deaths are not just related to chance. The vulnerability of people is the product of different factors combining internal

and external vulnerabilities. The "internal" vulnerability is assumed to be the capacity of response of each individual to face disasters in both psychological (knowledge, awareness of risk…) and physical aspects (age, disability…). The external vulnerabilities are related to the conditions in where the individual is living (e.g. kind of buildings, possibilities for sheltering…).

In return, these deaths show by default the effectiveness of certain preventive measures such as the construction of a refuge storey or a roof evacuation taking in account that these measures need to be accompanied by a "living awareness of risk" and a "culture of crisis" to make them operational. The comparison of two different scenarios of inundation and their aftermaths highlights the diversity of flooding phenomena. The profile of the victims, their age and the places of death are quite different. In the case of the Xynthia Atlantic floods, deaths are partly due to "external" criteria (e.g. the type of housing) and refer to a vulnerability that can be described as "passive". In the case of the flash floods in the Var Département, death outside of the home corresponds to an "active" vulnerability which assumes a "responsibility" of the victim and risk-taking. Comparison of the two cases also shows that the profiles of victims and circumstances of death depend on the time of the day and the type of flooding. There are very strong "temporal factors" relating the exposure of people to the hazards. Prevention and warning messages should address these specific vulnerabilities.

This shows that a specific approach of disaster prevention policy based on the local contexts is needed. As the population is ageing, especially in coastal areas and in the sunny southern part of France, the specific needs of elderly people and vulnerable people (i.e. isolated, marginalized people and persons with mental illness) must be addressed in emergency planning. This is currently not the case in France except for heat and cold waves. If the development of awareness of risk and of the culture of crisis is to be strengthened everywhere, certain measures such as "relocation of assets" or reducing the vulnerability of buildings are effective in the case of coastal flooding but more difficult to apply to flash flood-prone areas. The European Directive on Floods (ED/2007/60/EC), known as the Floods Directive, requires Member States to focus on the potential consequences of floods on health. The preliminary flood risk assessment should focus on the "significant adverse impacts on human health". France has undertaken this first assessment but more information on the potential lethal effect on flood-prone population would be helpful to design the territories to address in priority in flood prevention policy.

Acknowledgments The authors would like to acknowledge the assistance of the fire services of the departement of Vendée and Charentes-Maritime, especially Colonel Peuch and captain Dumas, M. Montaletang, L. Godet and Commandant Preault. Special thanks to doctor Fradin and Boisdin, to the CETE Méditerranée and the city of Draguignan for photographic documentation. Thanks to Thierry Sauzeau for information on the location of fatalities.

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