Original Article

Flood related mortality in a touristic island: Mallorca (Balearic Islands) 1960–2018

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Abstract
Although they exist, fatalities related to floods are a rare occurrence in the island of Mallorca. In the aftermath of the Sant Llorenç flash-flood of October 2018, which killed 13 people, a research was undertaken to develop database gathering information about the flood related victims on the island. The data was obtained from official reports and newspapers archives and was completed via field research and witnesses’ interviews. The difficulties in obtaining information reduced the period to the past 58 years. The results show that 25 people died as a result of a flood event in basins with an average area of 19.83 km² and a minimum of only 0.10 km². Breaking down further into demographics, 14 were male and 11 were female. The largest number of victims is included in the 18–65 age group and 36% of the fatalities were tourists and foreign residents. Even if the number of fatalities is small compared with other Mediterranean regions, the research results highlight the importance of the need of an increased safety campaign in the Islands, aimed both to residents and to tourists as well, taking into account the importance of Mallorca as a holidays resort in Europe.

KEYWORDS
age, circumstances, floods, gender, Mallorca, mortality, tourism

1 | INTRODUCTION

Floods are a common natural hazard worldwide that account for 47% of all weather-related disasters, affecting an average of 2.3 billion people (CRED, 2016). In 2018, there were 127 flood events worldwide according to the EM-DAT database criteria, affecting 700,000 people (CRED, 2019). The economic cost of such events is extensive (Barredo, 2007, 2009) and increasing yearly (Munich Re, 2018). Furthermore, flood related fatalities totalled 540,000 between 1980 and 2009 (Doocy, Daniels, Murray, & Kirsch, 2013). Recently, as of 2019, floods have caused fatalities in underdeveloped countries, such as India (1,000 deaths) or Indonesia (112 deaths) and in developing countries as well, like Iran (76 deaths) and China (83 fatalities) (WMO, 2019). Even in developed countries like the USA, flooding deaths are frequent. According to Lin and Skidmore (2019) between 1996 and 2015 there were 1,563 flood-related fatalities.

In Europe, floods are also common (Gaume et al., 2009; Gaume et al., 2016; Llasat et al., 2010) and costly, in terms of fatalities and damages. From 1991 to 1995 the cost of flood damages was estimated at 99 billion Euros (EEA, 2001). The number of casualties has been...
increasing throughout Europe as a result of large floods and flash-floods and showing a high variability regionally (Petrucci et al., 2019). Flood-related fatalities have been studied in Italy (Guzzetti, Stark, & Salvati, 2005; Salvati, Bianchi, Rossi, & Guzzetti, 2010), Greece (Diakakis & Deligiannakis, 2013; Diakakis & Deligiannakis, 2015), and Portugal (Pereira, Zêzere, Quaresma, Santos, & Santos, 2015), for historical or more recent events.

The 2002 floods in Central Europe were one of the largest damaging events across the continent, affecting Germany, Austria, and other countries. The event caused 110 fatalities and damage estimation exceeded 15 Billion Euros (Engel, 2004; Marsh & Bradford, 2003), thus prompting the European Union to undertake measures such as the 2007 directive on flood prevention, requiring EU members to study and prevent the flood risk (EU, 2007), with the preservation of the loss of life as one of the goals of the directive.

Since the directive began, there have been deadly events in Europe, such as the 2010 (26 fatalities) and 2015 (20 fatalities) floods in South France (Vinet, Boissier, & Saint-Martin, 2016), which can be considered as Mediterranean flash-floods or the 2013 event in Central Europe (25 deaths), caused by the overflow of large rivers.

Spain is no exception to the flood impact, mainly of the flash-flood type. A large number of events have been recorded from the past (Alberola, 2010; Barriendos et al., 2003; Ibisate & Sáenz, 2008; Llasat, Barriendos, Rodriguez, & Martin-Vide, 1999) and in recent decades (Domenech, Espejo, Ollero, & Sánchez, 2011; Espín, García, Ruiz, & Conesa, 2017; Guil-Guirado et al., 2019; Marzol, 2002; Máyer, 2002; Morales & Ortega, 2002; Sánchez et al., 2015).

Flood fatalities are also a common occurrence throughout Spain. Between 1950 and 2012, flood events have caused 1798 deaths (Ferrero, Castro, Pérez-Berrocal, & Arcos, 2017). Since the 1980s the number of victims is diminishing but there is an increase of the economic cost (Berga, 2011). During the 20th century there were at least five flash-flood events affecting Mediterranean streams or mountainous catchments with a high cost of human lives, being the Vallés flood in Barcelona the worst, with 441 people dead and 347 missing in 1962 (Martin-Vide & Llasat, 2018). The 1996 event in Biescas (Aragon), when a camping site was destroyed and 87 people killed, became a turning point in the Spanish flood policies, implemented afterwards to avoid future catastrophes (Ayala-Carcedo, 2002; Olcina, Saurí, Hernández, & Ribas, 2016). Even so, floods still produce deaths as the statistics demonstrate (Ferrero et al., 2017).

In this article, the research will focus on the flood related fatalities on the island of Mallorca. A database was created for the period 1960–2018 with the objective to gather the maximum information about victims, regarding age, gender, circumstances of the death and other valuable data. The results will allow identifying the main vulnerable groups by age and gender, as well as the circumstances that cause the largest amount of fatalities on the island and the most affected areas by such events.

## 2 RESEARCH AREA

The island of Mallorca is located in the Western Mediterranean basin (Figure 1). The largest of the Balearic Islands, Mallorca has a surface of 3,626 km². It has a varied relief, with an average slope of 15.48%, with a low land in the middle of the island (Es Pla), lying between two main mountainous areas, the Serra de Tramuntana to the north-west (1,445 m.a.s.l at the highest peak) and the Serres de Llevant to the southeast, with altitudes reaching 500 m on average. The island features are completed with small hilly areas (Es Pla), several alluvial plains (Palma, Inca, Sa Pobla, and Campos) and a carbonate Miocene platform in the southeast (Figure 2). Geological materials on the island are highly permeable, being sedimentary plains, calcareous reliefs and carbonate platforms of Miocene origin (91.57% of the island surface). Impervious areas can be found on marly planes and coastal wetlands (8.43% of the island surface).

Regarding rainfall, Mallorca is affected by intense precipitation events, linked to cyclogenic Mediterranean conditions and the geographical trends of the island. Average yearly rainfall is around 600 mm but with a high variability in terms of spatial and temporal distribution (Grimalt et al., 2006). The northern mountains can reach averages of 1,400 mm/year while the southern zones barely reach 400 mm/year. Seasonal distribution shows an autumn maximum and a summer minimum, with July being the driest month, usually without rainfall.

Rainfall in Mallorca is highly irregular and dry years alternate with profusely wet ones. Heavy rainstorms, that can occasionally reach 400 mm in 24 hr, are frequent and affect mainly the mountainous area in the north of the island, as well as the east coast (Grimalt et al., 2006).

In terms of surface runoff, the island is organised in four main basins following the main flow direction. The four are Northwestern, Northeastern, Southeastern, and Southwestern, all of them comprised by ephemeral streams, known locally as torrents. The largest catchments flow northwards and southwards to the bays located in both areas. Meanwhile, northwestern and southeastern catchments have smaller surfaces but steep drainage systems, thus being the most prone to torrential events (Figure 3).

Flooding on the island is the result of a combination of factors. On one hand, the torrential rainfall, with daily amounts which easily reach 100 mm (423 days from 1930 to 2018 on the island and the most affected areas by such events.

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to 2005), or 200 mm (50 days in the same period) and even 300 mm (6 days). The daily maximum was 536.5 mm in October in the Northwestern area of Mallorca, recorded in 1959. In the southern area, the record was 400 mm in October 1957. On the other hand, the location and structure of the surface runoff system helps to develop large flood peaks in short periods of time, due to the reduced surface and the morphology of the catchments.
Furthermore, the urbanisation of large areas of the island has contributed to increase the amount of impervious surfaces, thus increasing the flood risk as the land use has changed from agricultural land, highly permeable, to paved non pervious surfaces. 200.7 km² (5.54%) of the island surface corresponds to urban areas.

Severe floods are characterised by extreme peaks that exceed the capacity of torrent channels (Grimalt, Rodríguez-Perea, Corbí, Marcus, & Menorca, 1990). This overflow affects mainly alluvial plains and coastal areas, both of which register high human occupation since they host crowded touristic venues and facilities as well as the most fertile lands for farming activities.

Moreover, people's actions can increase the presence of floods. An example is the dry-stone system built to avoid soil erosion in farming lands. While this system reduces surface runoff, it can increase flood peaks when intense precipitation events collapse the system, causing debris-flow floods and an increase of the flood risk (Grimalt & Rosselló, 2018).

Historically, Mallorca has been affected by floods and between 1,403 and 2010, 223 severe events have been recorded (Grimalt & Rosselló, 2011). An especially affected area has been the city of Palma, capital of Mallorca. The town was built around Sa Riera stream mouth and the urban growth lead to an occupation of the flooding area. As a result, the 1,403 flood destroyed partially the city and killed 5,000 people (Grimalt, 1989), probably one of the most damaging events of European Middle Ages time.

Flood events with damages and victims have been occurring, even if damage level as the one above mentioned was never repeated, in Palma, the alluvial plains of Sa Pobla and Campos, and other towns crossed by streams like Manacor and Sóller.

From the 15th to the 19th century, the affected zones remained the same but during the 20th century a change occurred, related to agricultural and industrial development first, the tourism industry afterwards. The expansion of urbanisation led to the use of flood-prone areas, previously not used, but nowadays occupied by buildings, roads, streets, and so forth. As a result, the number of flooded areas increased since 1960, with a large number of floods affecting coastal towns.
Mallorca has a population of 896,038 inhabitants as of 2019 (IBESTAT, 2019a). Palma, the main city of the island, hosts almost half of the inhabitants (46.77%). The economy shows an important tertiarization, related to the tourism industry.

The increase of population from 363,199 in 1960 to 896,038 in 2019 is related to tourism as new jobs attracted population from mainland Spain and abroad. Unfortunately, new inhabitants do not know the territory where they live and are unaware of the existence of a flood risk, as the traditional risk culture, linked to agricultural practices, has almost disappeared. The massive tourist arrival is the summer months; more than 4,000,000 between June and October 2018 (IBESTAT, 2019b) increases the potential number of victims, as they are equally unaware of the risks they face while in holidays.

Related to the above mentioned figures, the regional government has identified 10 high-risk flood areas in Mallorca (DGRH, 2016) but further research, regarding historical affected areas (Grimalt & Rosselló, 2011), shows that 692,207 inhabitants of the island are located on municipalities affected by flood events, so a 78% of the population live on a place that can be affected by a flash flood.

3 SOURCES AND METHOD

From the InunIb database (Grimalt & Rosselló, 2011) a list of flooding events causing victims was obtained for the period 1960–2018. The data was cross-referenced with the information contained in the MeFP database (Petrucci et al., 2019), which contains the information about flood related fatalities within the HyMeX project regions of France, Greece, Italy, and Spain, but only covers the period 1981–2015.

It has to be pointed out that there are existing databases containing casualty's information. The best-known database is the CRED EM-DAT, with a large list of events that provides fatality information. Not all of the events are included, however all of the catastrophic ones are (Petrucci, Papagiannaki, et al., 2019; Vinet et al., 2016).

For the period 1981 to 2015, the EM-DAT database did not record fatalities in the Balearic Islands, when there were seven (Petrucci, Papagiannaki, et al., 2019). Once a first list was completed, a research in newspapers archives and official reports was undertaken. Data such as age, gender, nationality, causes, and circumstances of the death, was compiled and included on a spreadsheet.

The geographical position of the victims was mapped to point the exact locations of the death occurrence. Such information could provide valuable data in terms of the most dangerous places such as roads, bridges, etc.

4 RESULTS

A total of 25 fatalities were recorded in Mallorca for the research period. The main data about each one is summarised in Table 1.

4.1 Gender and age

Regarding gender, 14 victims were men and 11 women. These results are consistent with other research of flood-related mortality in Europe. Even so, it has to be highlighted that the number of female fatalities is higher than in other Mediterranean areas, where the male victims are usually twice the number of female fatalities (Pereira et al., 2017).
| Fatality ID | Date       | Meteorological season | Stream                | Circumstances                  | Location  | Age group | Sex | Origin  | Total rainfall event (mm) |
|------------|------------|------------------------|-----------------------|-------------------------------|-----------|-----------|-----|---------|-------------------------|
| 1          | 25.09.1962 | Autumn                 | Torrent Camp de Mar   | Outdoors, near water course   | Rural area| Unknown  | Male | Tourist | 160                     |
| 2          | 25.09.1962 | Autumn                 | Torrent Camp de Mar   | Outdoors, near water course   | Rural area| Unknown  | Female| Tourist | 160                     |
| 3          | 12.10.1973 | Autumn                 | Xaragall Lloseta      | Indoors, inside a building    | Urban area| 0–17     | Male | Local   | N/A                     |
| 4          | 17.02.1974 | Winter                 | Torrent de Coanegra   | Outdoors, on the road         | Rural area| 18–65    | Male | Local   | 270.7                   |
| 5          | 17.02.1974 | Winter                 | Torrent de Coanegra   | Outdoors, on the road         | Rural area| 18–65    | Male | Local   | 270.7                   |
| 6          | 21.04.1981 | Spring                 | Torrent d’Almedrà     | Outdoors, on the road         | Rural area| 18–65    | Female| Local   | 281                     |
| 7          | 06.09.1989 | Autumn                 | Torrent de Cas Corso  | Indoors, inside a building    | Urban area| 18–65    | Male | Local   | 272                     |
| 8          | 06.09.1989 | Autumn                 | Torrent de Cas Corso  | Indoors, inside a building    | Urban area| 0–17     | Male | Local   | 272                     |
| 9          | 06.09.1989 | Autumn                 | Torrent de Cas Corso  | Indoors, inside a building    | Urban area| 18–65    | Female| Local   | 272                     |
| 10         | 17.02.1974 | Winter                 | Torrent de Pula       | Outdoors, on the road         | Rural area| 18–65    | Female| Local   | 141.7                   |
| 11         | 12.09.2006 | Autumn                 | Xaragall a Alaró      | Indoors, inside a building    | Urban area| Over 65  | Female| Local   | 141                     |
| 12         | 06.09.1998 | Autumn                 | Sa Riera              | Outdoors, on the road         | Rural area| 18–65    | Female| Tourist | 112                     |
| 13         | 09.10.2018 | Autumn                 | Torrent de ses Planes | Outdoors, on the road         | Rural area| Over 65  | Female| Tourist | 257                     |
| 14         | 09.10.2018 | Autumn                 | Torrent de ses Planes | Indoors, inside a building    | Urban area| Over 65  | Male | Local   | 257                     |
| 15         | 09.10.2018 | Autumn                 | Torrent de ses Planes | Indoors, inside a building    | Urban area| Over 65  | Female| Local   | 257                     |
| 16         | 09.10.2018 | Autumn                 | Torrent de ses Planes | Outdoors, on the road         | Urban area| 18–65    | Female| Local   | 257                     |
| 17         | 09.10.2018 | Autumn                 | Torrent de ses Planes | Outdoors, on the road         | Urban area| 0–17     | Male | Local   | 257                     |
| 18         | 09.10.2018 | Autumn                 | Torrent de Ca n’Amer  | Outdoors, on the road         | Rural area| Over 65  | Female| Tourist | 257                     |
| 19         | 09.10.2018 | Autumn                 | Torrent de Ca n’Amer  | Outdoors, on the road         | Rural area| 18–65    | Male | Local   | 257                     |
| 20         | 09.10.2018 | Autumn                 | Torrent de Ca n’Amer  | Outdoors, on the road         | Rural area| Over 65  | Male | Tourist | 257                     |
| 21         | 09.10.2018 | Autumn                 | Xaragall de Son Dragó | Outdoors, near water course   | Rural area| 18–65    | Male | Local   | 257                     |
| 22         | 09.10.2018 | Autumn                 | Torrent des Revolts   | Indoors, inside a building    | Rural area| Over 65  | Male | Local   | 277.4                   |
| 23         | 09.10.2018 | Autumn                 | Torrent des Revolts   | Outdoors, on the road         | Rural area| 18–65    | Male | Foreign resident | 277.4       |
| 24         | 09.10.2018 | Autumn                 | Torrent des Revolts   | Outdoors, on the road         | Rural area| 18–65    | Female| Foreign resident | 277.4       |
| 25         | 09.10.2018 | Autumn                 | Torrent des Revolts   | Outdoors, on the road         | Rural area| 18–65    | Male | Foreign resident | 277.4       |
The age of the casualties is known for 23 of 25 dead people. Three age bands were used to distribute the flood victims. The highest number of deaths is within the group aged 18–65 years old (52.4%) while the lowest is in the 0–17 years old group (14.3%). The elderly group, over 65 years old, has 7 fatalities, four involving people aged between 80 and 89 and three between 70 and 79, something that confirms the vulnerability of the elderly when facing flood events, as they are likely to stay in flooded buildings (Jonkman & Kelman, 2005). The median age of a flood victim in Mallorca is 51.7 years old. The youngest victim was a 17-month old child whereas the oldest fatality was an 89 years old woman.

The results regarding age show similarities with other research throughout Europe but differ with results obtained in the United States where the victims fell largely on the 10–29 age group (Ashley & Ashley, 2008).

4.2 Origin of victims

An important question is if foreign people, such as tourists, are more vulnerable than local people when facing flood events (Vinet et al., 2016). Supposedly, local population is more aware of the flood risk but such knowledge is fading in Mallorca, as a result of an increasing tourism industry, which lead to the arrival of large amounts of migrants since the 1960s, as well as large numbers of visitors, mainly in summer and fall.

The origin of the 25 fatalities is known. They were divided into three groups: local residents, foreign residents, and tourists. The largest number of victims, 16, are comprised in the local population group while tourists’ fatalities are 6 and foreign residents 3. This number show how local inhabitants are more vulnerable to flooding, something that could be related to different factors, such as a largest number of local population being in the island in fall when the holidays season is finishing and also not obeying evacuation or safety instructions or trying to protect personal properties (Boudou, Lang, Vinet, & Coeur, 2016; Vinet et al., 2016). Furthermore, local fatalities can be related to a lack of awareness of the risk faced while driving into flooding streams or living in flood-prone areas.

4.3 Circumstances of death

All of the reported deaths have a known setting of occurrence. The data show that 68% of the fatalities happened outdoors while 32% were indoors.

Regarding the places where the deaths occurred, 8 people were trapped inside a building, 14 were on the road and 3 were near watercourses. The dynamics of the events are also known. The eight deaths inside buildings were trapped in flooded rooms, five in private houses, and three inside a hotel. The three victims of watercourses fell into the stream or were carried away to the sea. Finally, the 14 fatalities on the road were all inside cars.

The developed field research allowed the behaviour of the victims to be understood. Of those trapped inside a building, four were sitting or lying in bed and four were standing. Those carried away by water were on foot, walking close to the stream bed. Among the people killed

| TABLE 2 | Frequency of fatalities by decade |
|---|---|---|
| 1960–1969 | 2 | 8% |
| 1970–1979 | 3 | 12% |
| 1980–1989 | 4 | 16% |
| 1990–1999 | 1 | 4% |
| 2000–2009 | 2 | 8% |
| 2010–2018 | 13 | 52% |

FIGURE 4 Distribution of fatalities by month

FIGURE 5 Lighting conditions of events
inside a car, 11 were dragged by water while driving (trying to cross a bridge or a ford) and 3 were stopped and surprised by a flood wave.

The results show similarities with flood victims in Italy (Aceto, Pasqua, & Petrucci, 2017; Salvati et al., 2018) and Greece (Diakakis & Deligiannakis, 2013; Pereira et al., 2017) regarding places and activities during fatal events.

4.4 | Temporal distribution of fatalities

The evolution of flood mortality in Mallorca can be studied by its decadal frequency (Table 2). The number of fatalities is variable, with the highest number of victims in the current decade, but as a result of a single event, the October 9th 2018 flood in Sant Llorenç.
There is not a clear relation between flood related fatalities and the rainfall regime in the island. In fact, the 80s were the driest decade of the research period, (Caldentey, 2015), and the second one with more flood-related deaths, provoked by two events.

Monthly distribution shows the importance of rainfall as a flood generator in a Mediterranean environment. Between September and November, in less than 70 calendar days, 22 fatalities occur (88%). That being said, 7 months have not recorded a flood-related death during the research period (Figure 4).

Seasonal distribution follows the above mentioned pattern, which shows autumn as the predominant period with victims, which is related to being the season with the highest number of rainy days over 100 mm of rainfall, thus having more flood events. Meanwhile, summer is the period without victims, being the season with less precipitation in a Mediterranean rainfall regime.

To conclude with the temporal analysis, the daily distribution of the events was studied. To this end, the day was divided in four main categories, with the local times within each category varying accordingly with the daylight saving time schedule (Figure 5).

The largest amount of fatalities (13) is found during sunset, even if that number is the result of the single event of October 2018. The other 12 victims are evenly divided between sunrise, day, and night categories. Even if the results are not significant regarding people’s vulnerability, the data states that twilight is a dangerous time (Vinet et al., 2016). If sunrise and sunset is considered as twilight, then that time of the day accounts for 18 of the 25 deaths in the 58 years’ period.

### 4.5 Spatial distribution and catchment characteristics

The location of the fatalities is mainly in the Southeastern coast catchments, 17 out of 25 deaths. Five victims

**TABLE 3 Watersheds characteristics**

| Basin | Watershed | Stream | Fatalities ID | Catchment surface (km²) | Catchment perimeter (km) | Gravelius coefficient | Concentration time (hr) | Date       |
|-------|-----------|--------|---------------|--------------------------|--------------------------|----------------------|------------------------|------------|
| SE    | Cas Corso | Torrent de Cas Corso | 7-8-9 | 1.10 | 8.3 | 1.7 | 1.45 | 06.09.1989 |
|       | Pula      | Torrent de Pula | 10 | 11.81 | 19.0 | 7.8 | 1.46 | 10.11.1990 |
|       | Ca n’Amer | Torrent de Ca n’Amer | 12 | 23.23 | 26.3 | 11.1 | 2.65 | 09.10.2018 |
|       |           | Torrent de ses Planes | 14-15-16-17 | 23.47 | 27.0 | 10.9 | 2.86 | 09.10.2018 |
|       |           | Torrent de ses Planes | 18-19-20 | 73.71 | 51.8 | 17.9 | 5.75 | 09.10.2018 |
|       | Canyamel  | Torrent des Revolts, Artà | 21 | 1.23 | 6.4 | 2.4 | 0.99 | 09.10.2018 |
|       |           | Torrent de Canyamel | 23 | 32.58 | 31.5 | 13.0 | 3.09 | 09.10.2018 |
|       |           | Torrent de Canyamel | 24-25 | 32.97 | 32.3 | 12.8 | 3.26 | 09.10.2018 |
| NE    | Muro      | Xaragall urbà a Lloseta | 3 | 1.57 | 6.3 | 3.1 | 0.82 | 12.10.1973 |
|       |           | Torrent d’Almedrà | 6 | 37.44 | 48.5 | 9.7 | 4.32 | 21.04.1981 |
|       |           | Xaragall a Alaró | 11 | 0.10 | 1.3 | 0.9 | 0.17 | 12.09.2006 |
| SW    | Camp de Mar | Torrent des Camp de Mar | 1-2 | 6.40 | 11.8 | 6.8 | 1.32 | 25.09.1962 |
|       | Torrent Gros | Torrent de Coanegra | 4-5 | 29.75 | 33.5 | 11.2 | 3.66 | 17.02.1974 |
|       | Sa Riera  | Sa Riera | 12 | 2.17 | 7.8 | 3.5 | 1.05 | 17.10.2007 |
are located in the Southwest coast basin and three in the Northeastern Mallorca basin (Figure 6).

The area with the largest number of victims is the one that has the lowest mountains, an average of 500 mm/year of rainfall and, on a 70 years period, 93 days over 100 mm of rain (24 hr) were recorded.

The distribution highlights the importance of flash floods from very small to medium sized watersheds, like the ones located in the east of Mallorca (Table 3). There are medium and small basins and, in some cases, very small. There is no clear dependence on the shape of the basin, although the circular ones (lowest values of the Gravelius compactness coefficient) predominate but in some cases the basins are also extremely long shaped (higher values of the Gravelius compactness coefficient). The largest catchments regarding surface, which are flowing to the north and south of the island, have only caused one fatality during the study period. Furthermore, almost all the victims are located in small tributaries of largest streams able to surprise suddenly with high peak flows.

It is also important to know the environment in which events happened. To this end, the research divided the settings between rural and urban. The results showed that 36% of the incidents were located in urban areas, whereas 64% took place in rural environments.

Within the urbanised environments, no deaths are found in the largest cities of Mallorca. Instead, fatalities are located on traditional townships (4 fatalities) and on coastal touristic urbanizations (3 fatalities). Almost all the victims were trapped inside flooded rooms or carried away by water. Only two victims were in a car, which was on a street when surprised by the flood wave.

Regarding fatalities in rural areas, 13 victims occurred while driving, 5 for leisure activities while 8 drove in work related matters. One death took place inside a country house.

5 | CONCLUSIONS

Nine flash-flood events in the period 1960–2018 caused 25 casualties in Mallorca. Examined by age, the data reveal that elderly people, older than 65 years old, are the most vulnerable to flood-related deaths, even if the highest number of victims fell within the 18–65 years old age group. Regarding gender, men are the most vulnerable (56%) but the percentage is not as high as other research shows (Jokman & Kelman, 2005; Petrucci, Aceto, et al., 2019; Petrucci, Papagiannaki, et al., 2019; Vinet et al., 2016).

Mortality rate is higher within local people. In fact, 64% of the fatalities were local residents while 36% were foreigners. The numbers highlight as well the people’s failure to reckon and understand the flood risk and climatic reality of where they live. Even so, a voluntary risk behaviour was not observed on the fatalities.

Taking into account the dynamics of the event, the majority of victims were in cars, driving or stopped on the road (56%) while 32% were trapped inside a building, largely elder people.

Fatalities during the research period are not directly related to the recent urban growth. Only four fatalities are located on recently built areas (Felanitx, 1989 and Artà, 2018), which are a result of the expansion from the 1960s onwards.

On the other hand, it must be noted that the increase of traffic (car pool) and parking areas over the island has had an effect on flood fatalities and damages. To this end, being on the road by car is, by far, the most common circumstance of death, which is similar as research in Calabria (Italy) had found (Aceto et al., 2017). Such result can be related to the increase of the car pool on the island (from 452,424 vehicles in 1996 to 788,506 vehicles in 2018), which increases the pressure on the road system, mainly during the summer and fall months.

Furthermore, cars have changed compared to the past and those changes affect their behaviour once inside the running water. Modern vehicles weight less and the cockpit is watertight, thus increasing the buoyancy and allowing being swept away by water easily. In fact, a car was carried away 2,750 m at the Sant Llorenç flash flood with four people trapped inside.

The foreseen changes on the car pool, with a probable increase of the electric cars will change the cars behaviour while on the flood waters, as they will weigh more than gas vehicles.

Spatially, the highest number of fatalities has happened in the North and Southeastern catchments (80%). Furthermore, the results show the risk of very small basins with 40% of fatalities located in watersheds smaller than 6.5 km².

Temporally, the fall season is the deadliest, with 88% of victims. The fact can be linked to rainfall; in fact, autumn months are the wettest in the island (Grimalt, Laita, Rosselló, Caldentey, & Arrom, 2006), yet summer, the driest season, has no fatalities recorded. It is also related to the extended arrival of tourists in September and October as all foreign victims have died during those months.

The detailed database built for this research allows a study of flood mortality which can improve the knowledge about vulnerability by gender and age, as well as location and circumstances within the island.

Furthermore, the results of this research show that population is largely unaware of the risks associated with flooding. A program related to flood risk safety should be implemented at the citizen level, thus educating people
to act correctly in a case of flood. Such policies became more important if the number of tourists visiting the island is taken into account. It is a large population living and travelling through flood-prone areas, without knowing they face such risk, especially during the fall season, which is becoming busier year after year.

A future research step, considered by the authors, is the use of citizen-science to study flood events. The use of web-based observations (Milanesi et al., 2016), interviews (Macchione et al., 2019) or/and questionnaires can be a useful tool to study risk-taking behaviours and to evaluate flood-risk awareness by the affected population, especially among residents and tourists.

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CONFLICT OF INTEREST
The authors declare there is no conflict of interest.

DATA AVAILABILITY STATEMENT
Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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REFERENCES
Aceto, L., Pasqua, A. A., & Petrucci, O. (2017). Effects of damaging hydrogeological events on people throughout 15 years in a Mediterranean region. *Advances in Geosciences, 44*, 67–77.
Alberola, A. (2010). Riadas, inundaciones y desastres en el Sur valenciano a finales del siglo XVIII. *Papeles de Geografía, 51–52*, 23–32.
Ashley, S. T., & Ashley, W. S. (2008). Flood fatalities in the United States. *Journal of Applied Meteorology and Climatology, 47*, 805–818.
Ayala-Carcedo, F. J. (2002). La inundación torrencial catastrófica del camping “Las Nieves” del 7 de agosto de 1996 en el cono de deyeción del Arás (Biescas, Pirineo aragonés). In F. J. Ayala-Carcedo & J. Olcina Cantos (Eds.), *Riesgos Naturales* (pp. 889–912). Barcelona, Spain: Ariel.
Barredo, J. I. (2007). Major flood disasters in Europe: 1950–2005. *Natural Hazards, 42*(1), 125–148. https://doi.org/10.1007/s11069-006-9065-2
Barredo, J. I. (2009). Normalised flood losses in Europe: 1970–2006. *Natural Hazards and Earth System Sciences, 9*, 97–104.
Barriendos, M., Coeur, D., Lang, M., Llasat, M. C., Naulet, R., Lemaître, F., & Barrera, A. (2003). Stationary analysis of historical flood series in France and Spain (14th–20th centuries). *Natural Hazards and Earth System Sciences, 3*(6), 583–592.
Berga, L. (2011). Las inundaciones en España. La nueva directiva europea de inundaciones. *Revista de Obras Públicas, 3520*, 7–18.
Boudou, M., Lang, M., Vinet, F., & Coeur, D. (2016). Lessons from analysing mortality from six major events in France (1930–2010). *Floodrisk 2016. 3rd European Conference on Flood Risk Management. E3S Web of Conferences 7*, 06005. doi: https://doi.org/10.1051/e3sconf/20160706005.
Caldentey, J. (2015). Seguirmos la circulación atmosférica a la Mediterrània Occidental. (PhD thesis). Palma de Mallorca: Universitat de les Illes Balears.
Center for Research on the Epidemiology of Disasters. (2016). *The human cost of weather related disasters 1995–2015*. Brussels: CRED-EM-DAT-UNISDR.
Center for Research on the Epidemiology of Disasters. (2019). *Disasters 2018: Year in review*. CRED Crunch, issue number 54. EM-DAT. UC Louvain.
DGRH. (2016). *Mapas de peligrosidad y riesgo de inundación en la demarcación hidrológica de Baleares*. Conselleria de Media Ambient, Agricultura i Pesca. Govern de les Illes Balears. Palma de Mallorca.
Diakakis, M., & Deligiannakis, G. (2013). Changes in flood mortality during the last 50 years in Greece. *Bulletin of the Geological Society of Greece, XLVII*(3), 1397–1406.
Diakakis, M., & Deligiannakis, G. (2015). Flood fatalities in Greece: 1970–2010. *Journal of Flood Risk Management, 10*(1), 115–123.
Domenech, S., Espejo, F., Olleró, A., & Sánchez, M. (2011). Peligrosidad por inundaciones en una cuenca no aforada: El río Sosa en Monzón (Huesca) y el evento de agosto de 2006. *Geographical, 59–60*, 95–108.
Doocy, S., Daniels, A., Murray, S., & Kirsch, T. D. (2013). The human impact of floods: A historical review of events and systematic literature review. *PLOS Currents Disasters*. https://doi.org/10.1371/currents.dis.f4deb457904936b07c09daa98ee8171a.
Authors
Engel, H. (2004). The flood event 2002 in the Elbe river basin, causes of the flood, its course, statistical assessment and flood damages. *La Houille Blanche, 6*, 33–36.
Espín, D., García, D., Ruiz, V., & Conesa, C. (2017). Las lluvias torrenciales e inundaciones de los días 17 y 18 de diciembre de 2016 en la región de Múrcia con particular incidencia en el área vertiente del Mar Menor. *Ingeniería del Agua, 21*(4), 213–229.
European Environment Agency. (2001). *Sustainable water use in Europe, part 3: Extreme hydrological events: Floods and droughts*. Environmental Issue Report 21. Copenhagen.
European Union. (2007). *Assessment and management of flood risks*. Directive 2007/60/EC. European Parliament and Council.
Ferrero, E., Castro, R., Pérez-Berrocal, J., & Arcos, P. (2017). La mortalidad por desastres en España: Un análisis del periodo 1950–2012. *Índice de Enfermería, 261*(2), 113–117.
Gaume, E., Bain, V., Bernardara, P., Newinger, O., Barbuc, M., Bateman, A., ... Viglione, A. (2009). A collation of data on European flash floods. *Journal of Hydrology, 367*, 70–78.
Gaume, E., Borga, M., Llasat, M. C., Maouche, S., Lang, M., & Diakakis, M. (2016). Mediterranean extreme floods and flash floods. (Subchapter 1.3.4). In J. P. Moatti & S. Thiébault (Eds.), *The Mediterranean under climate change* (pp. 133–144).
Grimalt, M. (1989). Les inundacions històriques de sa Riera. Traballs de Geografia, 42, 19–26.

Grimalt, M., & Llasat, J. (2011). Anàlisi històrica de les inundacions a les Illes Balears. Palma: Conselleria d’Agricultura, Medi Ambient i Territori.

Grimalt, M., & Rosselló, J. (2018). Traditional flood mitigation measures in Mallorca. In Antronicu, L., & Marincioni, F. (Eds.). Natural hazards and disaster risk reduction policies. Geographies of the Anthropocene, vol. 1, number 2. II Sileno Edizioni., pp. 243–260.

Grimalt, M., Tomás, M., Alomar, G., Martín-Vide, J., & Moreno-Garcia, M. C. (2013). Determination of the Jenkinsoon and Collison’s weather types for the Western Mediterranean basin over the 1948–2009 period: Temporal analysis. Atmosfera, 26(1), 75–94.

Grimalt, M., Rodríguez-Perea, A., Corbí, A., Marcus, A. & Menorca, P. (1990). Caudales punta de avenidas y morfología de cuencas en Mallorca. In Gutiérrez, L. Peña, J. L. & Lozano, M. V. (Eds.) Actas I Reunión Nacional deGeomorfología, volumen 2. Cuenca, pp. 427–436.

Grimalt, M., Laita, M., Rosselló, J., Caldentey, J. & Arrom, J. M. (2011). Les inundacions històriques de sa Riera. Traballs de Geografia, 45(1), 219–238.

Guerrero, A., Pérez, A., & Lopez-Martínez, F. (2019). SMC-floods database: A high resolution press database on floods for the Spanish Mediterranean coast (1960–2015). Natural Hazards and Earth System Sciences, 19, 1955–1971. https://doi.org/10.5194/nhess-2019-10

Guzzetti, F., Stark, C. P., & Salvati, P. (2005). Evaluation of flood and landslide risk to the population of Italy. Environmental Management, 36(1), 15–36.

IBESTAT. (2019a). Padró de població de Mallorca.

IBESTAT. (2019b). Estadística turística. Retrieved from www.caib.es/ibestat/estadisticas/economia/turisme.

Ibírate, A., & Sáenz, A. (2008). Aproximación al estudio de las crecidas históricas del rio Ora: Registro de eventos (siglos XVI—XX). Fórum de Sostenibilidad, 2, 79–90.

Jonkman, S. N., & Kelman, I. (2005). An analysis of the causes and circumstances of flood disaster deaths. Disasters, 29(1), 75–97.

Lin, J., & Skidmore, M. (2019). Flood fatalities in the United States. The roles of socioeconomic factors and the National Flood Insurance Program. Southern Economic Journal, 85(4), 1032–1057. https://doi.org/10.1002/soej.12330

Llasat, M. C., Llasat-Botija, M., Prat, M. A., Porcú, F., Price, C., Mugnai, A., ... Nicolaides, K. (2010). High-impact floods and flash floods in Mediterranean countries: The FLASH preliminary data-base. Advances in Geosciences, 23, 47–55.

Llasat, M. C., Barriendos, M., Rodríguez, R., & Martín-Vide, J. (1999). Evolución de las inundaciones en Cataluña en los últimos 500 años. Ingeniería del Agua, 6(4), 257–266.

Macchione, F., Costabile, P., Costanzo, C., & de Lorenzo, G. (2019). Extracting quantitative data from non-conventional information for the hydraulic reconstruction of past urban flood events. A case study. Journal of Hydrology, 576, 443–465. https://doi.org/10.1016/j.jhydrol.2019.06.031

Marsh, T. J., & Bradford, R. B. (2003). The floods of August 2002 in Central Europe. Weather, 58, 168.

Martin-Vide, J. P., & Llasat, M. C. (2018). The 1962 flash flood in the Rubí stream (Barcelona, Spain). Journal of Hydrology, 566, 441–454. https://doi.org/10.1016/j.jhydrol.2018.09.028

Marzol, M. V. (2002). Lluvias e inundaciones en la ciudad de Santa Cruz de Tenerife. In Guijarro, J. A., Grimalt, M., Laita, M., & Alonso, S. (Eds.) El agua y el clima. Publicaciones de la AEC, serie A n° 3, pp. 461–470.

Mayer, P. (2002). Desarrollo urbano e inundaciones en la ciudad de Las Palmas de Gran Canaria (1869–2000). Investigaciones Geográficas, 28, 145–159.

Milanesi, L., Pilotti, M., & Bacchi, B. (2016). Using web-based observations to identify thresholds of a person’s stability in a flow. Water Resources Research, 52, 7793–7805. https://doi.org/10.1002/2016WR019182

Moraes, C. G., & Ortega, M. T. (2002). Frecuencia y distribución de los episodios de inundación en la cuenca del Pisuerga en las últimas cuatro décadas. In Guijarro, J. A., Grimalt, M., Laita, M. & Alonso, S. (Eds.) El agua y el clima. Publicaciones de la AEC, serie A n° 3, pp. 483–494.

Munich Re. (2018). TOPICS Geo. Natural catastrophes. Retrieved from https://www.munichre.com/site/touch-publications/get/documents_E711248208/mr/assetpool/shared/Documents/5_Touch/_Publications/TOPICS_GEO_2017-en.pdf.

Oclina, J., Sauri, D., Hernández, M., & Ribas, A. (2016). Flood policy in Spain: A review for the period 1983–2013. Disaster Prevention and Management, 25(1), 1–20.

Pereira, S., Diakakis, M., Deligiannakis, G., & Zézere, J. L. (2017). Comparing flood mortality in Portugal and Greece (Western and Eastern Mediterranean). International Journal of Disaster Risk Reduction, 22, 147–157. https://doi.org/10.1016/j.ijdrr.2017.08.064

Pereira, S., Zézere, J. L., Quaresma, I., Santos, P. P., & Santos, M. (2015). Mortality patterns of hydro-geomorphologic disasters. Risk Analysis, 36(6), 1188–1210. https://doi.org/10.1111/risa.12516

Petrucci, O., Aceto, L., Bianchi, C., Bigot, V., Brázdil, R., Pereira, S., ... Zézere, J. L. (2019). Flood fatalities in Europe, 1980–2018: Variability, features, and lessons to learn. Water, 11, 1682.

Petrucci, O., Papagiannaki, K., Aceto, L., Boissier, L., Kotroni, V., Grimalt, M., ... Vinet, F. (2019). MEFF: The database of Mediterranean flood fatalities (1980 to 2015). Journal of Flood Risk Management, 12, e12461. https://doi.org/10.1111/jfr3.12461

Salvati, P., Bianchi, C., Rossi, M., & Guzzetti, F. (2010). Societal landslide and flood risk in Italy. Natural Hazards and Earth System Sciences, 10, 465–483. https://doi.org/10.5194/nhess-10-465-2010

Salvati, P., Petrucci, O., Petrucci, M., Bianchi, C., Pasqua, A. A., & Guzzetti, F. (2018). Gender, age and circumstances analysis of flood and landslides fatalities in Italy. Science of the Total Environment, 610–611, 867–879.

Sánchez, M., Ballarin, D., Mora, D., Ollero, A., Serrano, M., & Saz, M. A. (2015). Las crecidas del Ebro medio en el comienzo del siglo XXI. In de la Riva, J., Ibarra, P., Montorio, R., & Rodrigus, M. (Eds.). Anàlisis espacial y representación geográfica: Innovación y aplicación. Zaragoza: Asociación de Geógrafos Españoles, pp. 1853–1862.
Vinet, F., Boissier, L., & Saint-Martin, C. (2016). Flashflood-related mortality in Southern France: First results from a new database. Floodrisk 2016. 3rd European Conference on Flood Risk Management. E3S Web of Conferences 7, 06001. https://doi.org/10.1051/e3sconf/20160706001

WMO. (2019). Provisional statement on the state of the Global Climate in 2019. World Meteorological Organization. Retrieved from public.wmo.int/en/.

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