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Key Points:

- This paper seeks to understand the hydrological, individual, and collective determinants of mental resilience to flooding
- The role of water flow velocity on mental health degradation is revealed via the construction of an innovative Hazard Rate Class Index
- Insights for building flood resilience to enhance posttraumatic distress management are provided

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The effect of flooding on mental health: Lessons learned for building resilience

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Abstract Risk management and climate adaptation literature focuses mainly on reducing the impacts of, exposure to, and vulnerability to extreme events such as floods and droughts. Posttraumatic stress disorder is one of the most important impacts related to these events, but also a relatively under-researched topic outside original psychopathological contexts. We conduct a survey to investigate the mental stress caused by floods. We focus on hydrological, individual, and collective drivers of posttraumatic stress. We assess stress with flood-specific health scores and the GHQ-12 General Health Questionnaire. Our findings show that the combination of water depth and flood velocity measured via a Hazard Class Index is an important stressor; and that mental health resilience can be significantly improved by providing the population with adequate information. More specifically, the paper shows that psychological distress can be reduced by (i) coordinating awareness of flood risks and flood protection and prevention behavior; (ii) developing the ability to protect oneself from physical, material and intangible damage; (iii) designing simple insurance procedures and protocols for fast recovery; and (iv) learning from previous experiences.

1. Introduction

Within risk management literature, there is growing interest in extreme events and effective ways to adapt to their impacts. This has been triggered by evidence that suggests that human health impacts related to climatic events have increased and will continue to do so in the future [*Watts et al*., 2015]. Adaptation to climate change seeks to reduce exposure and vulnerability. It can involve both public and private initiatives, hard (infrastructure based) options or other, softer possibilities (such as behavioral measures), and planned (i.e., policy based) or autonomous adaptation (ecological or welfare/market based) practices [*International Panel on Climate Change*, 2007; *Markandya and Watkiss*, 2009; *Sovacool*, 2011].

Climate change is characterized by deep uncertainty related to future impacts and, consequently, economically rational decision-making with regards to investments in (hard) infrastructures becomes complicated [*Markandya*, 2014]. In such a context, paying attention to soft, autonomous adaptation measures such as those that prioritize natural capital, community control, simplicity, and appropriateness [*Sovacool*, 2011] can be highly relevant. Moreover, there is a clear consensus regarding the need for adaptation practices to reduce impacts of extreme events and enhance the physical resilience of communities but less attention has been paid to the capability of individuals and societies to cope with the stress generated by such events.

Natural events such as floods expose people to several health-related problems from morbidity to mortality [*Alderman et al*., 2012]. Survivors can experience longer-term psychosocial effects such as distress, anxiety, pain, depression, and social dysfunctions. Severe distresses in the worst cases may become mental disorders or so-called psychopathologies [*Watts et al*., 2015]. Distress may occur during the event itself or after the event. The latter is known as post-traumatic stress disorder. There is a spectrum of such disorders: most of the psychological symptoms resulting from a disaster are a normal reaction to an abnormal event that do not need to be pathologized and do not result in clinical disorders [*Bonanno*, 2004; *Stein et al*., 2007].

Several risk factors interact to determine the degree to which people suffer psychologically from natural disasters [*Alderman et al*., 2012; *Fernandez et al*., 2015]. They include factors related to the hazard itself that characterize flood severity to people such as water depth, flood type and duration, and factors related to negative consequences of floods such as injuries, threat to life, property damage, financial losses, and displacement. The reasons why people develop psychological distress can be multiple. They can be related to individual skills and experience with flooding, autonomous actions taken to protect family, or belongings or to the taking out of insurance. However, these individual decisions also reflect how a society or community performs in managing risk. Indeed, the degree of awareness of individuals is also linked to the communication of risk. Reliance on insurance compensation and the relationship with insurers during the claim procedure may also influence distress in the aftermath of a flood.

We thus argue that the interplay between human resilience [*Bonanno*, 2004] and community resilience [*Norris et al*., 2008; *Tobin*, 1999] can limit the psychological consequences of the event. Human resilience reflects the ability of individuals to maintain relatively stable, healthy levels of psychological and physical functioning [*Bonanno*, 2004]. Community resilience relates to a process linking a set of network adaptive capacities to a positive path of functioning and adaptation in a population after disturbance [*Norris et al*., 2008]. The development of mental resilience skills thus has both individual and collective level influences [*Davydov et al*., 2010]. In this sense, individual resilience mechanisms might be innate or might have been developed through external influences from the community or the society; a community develops protective factors that enhance human resilience [*Castleden et al*., 2011]. We therefore consider resilience as the process that links adaptive capacities, be they individual or collective, to the outcome of adaptation to psychological distress from flooding and we test those factors that could favor such adaptation or could worsen psychological distress.

This paper seeks to understand what affects the degradation of well-being that results from flooding and thus what risk factors drive human and community resilience. Our main objective is to understand what factors make some individuals suffer less than others from a disaster insofar as they are able to experience or have experienced circumstances in their social environment that help them to recover and to maintain a stable, healthy level of psychological and physical functioning. We also seek to contribute to the understanding of the role of adaptation to psychological distress related to flooding. We measure changes in psychological distress as a chronic change in subjective well-being [*Campbell*, 1976; *Diener*, 1984] regardless of a threshold on the scale of pathological cases, rather than taking a psychopathological approach leading to the identification of clinical caseness [*Jackson*, 2007], because on most occasions the proportion of people who develop a psychopathology is not a majority [*Bonanno*, 2004]. This approach enables us to detect conditions favorable to psychological distress prevention and to resilience building before a psychopathology develops. To that end we use two scores to measure well-being: a nonevent-specific measure using the General Health Questionnaire (GHQ-12) commonly used in flood-related studies [*Fernandez et al*., 2015] and an event-specific self-reported question. We apply the method to a representative sample of the population of the Basque Country, Spain.

Section 2 develops the methodology used to measure well-being in the questionnaire. Section 3 presents the results: unidimensional and multidimensional analyses of the risk factors that can potentially affect health scores. Section 4 looks at effective ways to build resilience, providing some insights with regards to collective and individual adaptation possibilities. Section 5 highlights some limitations of the study and section 6 offers some concluding remarks.

2. Methodology

A survey was conducted in the Basque Country, Spain (Cantabrian river basin) in spring 2015. Data were collected in face-to-face interviews with self-administrated sections and 300 households which had experienced floods were surveyed. For this population, living on floodplains according to official flood maps, we used a stratified random sampling method with age and gender ranges as strata. The questionnaire, adapted from *Department for Environment Food and Rural Affairs* [2005], included a section with questions about the flooded property, household members, nature of flooding, and associated damage. This was followed by a section on the health impacts of flooding and, finally, a section with socio-demographic questions. We restricted the sample to 222 observations due to missing data and inconsistent responses, and limited it to those who were older than 10 at the time of the worst flood they had experienced. The households included are located in 14 different municipalities. The sample is nearly equally distributed between towns with fewer than 10,000 inhabitants, towns between 10,000 and 20,000 inhabitants and towns with over 20,000 inhabitants. The household members interviewed were equally distributed between male and female, the oldest being 92 and the youngest 21 years old. The average age was 53.

Most of the literature measuring flood-related subjective well-being considers short/medium term events preceding the survey by 1–30 months, as reviewed in *Alderman et al*. [2012]. However, to capture potential long term changes in psychological well-being due to flooding we did not limit inclusion in the survey to a single flood event since there is no clear evidence of how long psychological distress effects of natural disasters can last. *Bland et al*. [1996] find psychological impacts on Neapolitan men 7 years after an earthquake, *Sekulova and van den Bergh* [2016] survey psychological distress from flooding lasting up to 6 years in Bulgaria and *Hu et al*. [2015] find such effects 13 years later in China. As a result of our unrestrictive time frame, 43% of the respondents in our survey indicated that the worst flood event that they had experienced was in 1983; for around 13% it was in 2008 or 2009, and for 27% of the sample it was in 2015.

2.1. Mental Health Scores

2.1.1. The GHQ-12 General Health Questionnaire

The GHQ-12 is a measure of psychological morbidity related to mental health problems resulting from anxiety, social dysfunction, and loss of confidence [*Goldberg*, 1978]. It is a self-administered screening questionnaire comprising 12 items, equally divided between positively (PP) and negatively (NP) phrased statements. Each item is rated on a four-point scale: "[1]-more than usual," "[2]-same as usual," "[3]-less than usual," and "[4]-much less than usual" for the positively phrased statements and "[1]-not at all," "[2]-no more than usual," "[3]-rather more than usual," and "[4]-much more than usual" for the negatively phrased statements. The 12 items are listed in Appendix Table A1. A GHQ score is obtained as a sum of the scores for each item, and three scores are used [*Goodchild and Duncan-Jones*, 1985]. The first is the *conventional GHQ score*, where each item is scored by setting scales [1] and [2] to 0 and scales [3] and [4] to 1. The second is the *chronic GHQ score* (C-CHQ), which results from the fact that a "no more than usual" response in a negatively phrased statement might indicate chronic illness and should not be scored as a healthy case [*Goodchild and Duncan-Jones*, 1985], so for NP items the scale [1] is set to 0 and the scales [2], [3], and [4] to 1. Finally, a *Likert GHQ score* is obtained by scoring the four items from 0 to 3. As a result, GHQ and C-GHQ scores vary from 0 to 12 and the Likert GHQ score, which is more differentiated, varies from 0 to 36.

The GHQ-12 is a nonevent-specific questionnaire. To measure flooding-specific impacts on health and to capture the potential health deterioration, the GHQ-12 was used retrospectively here with two time references. Respondents were asked to refer first to *the past few weeks* (GHQ-base) preceding the interview and second to the time when the health effects of the worst flooding were at their most severe (GHQ-worst).

2.1.2. Self-Reported Score

A question on the general effect of flooding was used as a subjective measure of health impacts [*Department for Environment Food and Rural Affairs*, 2005]. It is rated from 0 to 10, namely from "no effect" to "extremely serious." This question was preceded by self-reported questions on the impact of 12 specific items, on the same 0 to 10 scale. Those items refer to damages, worries, or difficulties in recovery experienced. The significant correlation found between most of these items strengthens the use of one general self-reported question to capture flood-specific impacts on health. The different items and correlations are reported in Appendix Table A2.

2.1.3. Estimation of Mental Health Deterioration

Prior mental health status is recognized as a confounder of post-traumatic stress: individuals with poor pre-event mental health are more likely to develop mental disorders after a natural disaster [*Mason et al*., 2010; *Tunstall et al*., 2006]. We thus focus on the deterioration of mental health status to capture psychological distress. Taking the GHQ-base as a benchmark referencing the current health of respondents, we measure potential deterioration as the difference between the GHQ for the worst time of the flood and the GHQ for the past few weeks. We also consider nonzero scores for the self-reported measure as a signal of health deterioration.

These changes in health status are thus interpreted as a change in household well-being and not necessarily as an increase in cases of mental illness when a score threshold defines clinical caseness (see *Goldberg et al*. [1997, 1998] and *Jackson* [2007] for clinical caseness). The estimate of deterioration relocates the impact of flood recording (GHQ-worst) on the basis of the reference health status. We thus consider the mental health impact of flooding in relation to an individual's health status instead of an absolute score. Consequently, deterioration in mental health is measured irrespectively of the level of the health score at the worst time of the flood: the same deterioration score can be obtained by individuals with high health scores and those with low scores on the scale. We interpret this change as a subjective measure of an individual's well-being [*Campbell*, 1976; *Diener*, 1984].

The four health scores, *GHQ*, *C-GHQ*, *Likert GHQ*, and *Self-reported*, are scaled from 0 to 10, 0 to 12, and 0 to 36. To consider the count data characteristic of health scores and the existence of a known upper bound in each score, we use a binomial Quasi Maximum Likelihood Estimator—QMLE [*Wooldridge*, 2002]. Let y_i be the health score of observation i and n_i the upper bound. y_i is considered as the sum of n_i independent Bernoulli random variables. The conditional mean is $E(y_i|x_i,n_i)=n_i p(x_i,\beta)$, where x_i is a set exogenous variables and p is a cumulative distribution function bounded between zero and one; for this distribution we take a logistic function. The QMLE maximizes the sum of the binomial quasi log likelihood over the sample.

2.2. Hazard Rate Class Index

The severity of flooding has traditionally been considered as one of the main factors that can drive mental disorders for those who experience a flood. Many authors take water depth as a proxy for flood severity. For example, *Lamond et al*. [2015], *Paranjothy et al*. [2011], and *Tunstall et al*. [2006] find that the prevalence of mental health symptoms rises with the level of flood water. Another element in characterizing severity is flow velocity. The role of this element has been studied only in relation to physical health, e.g., fatalities and injuries [*Foudi et al*., 2015; *Jonkman and Penning-Rowsell*, 2008; *Penning-Rowsell et al*., 2005] and to infrastructures [*Kreibich et al*., 2009; *Thieken et al*., 2005], but not to mental health. According to *Department for Environment Food and Rural Affairs* [2006], the degree of hazard that a flood presents to people depends on both the depth and the velocity of floodwaters. Based on a combination of velocity and depth, *Department for Environment Food and Rural Affairs* [2006] classifies potential flood hazard impacts on physical health into different hazard classes: low, moderate, significant, and extreme.

The combination of velocity and depth factors in hazard classes offers a broader picture of hazards than traditional approaches do. However, collecting this information can be subject to measurement errors since flow velocity and water depth are not obvious to the respondents who report them. Flow velocity, accurately measured in meters per second [*Department for Environment Food and Rural Affairs*, 2006], is difficult to apprehend for nonexperts. Also, the observed water depth at properties is reported based on the perceptions and memories of respondents, which can be subject to overvaluation, as occasionally observed in our data set, for example. We thus develop a *hazard rate class index* for mental health that minimizes measurement errors to detect different flood hazards in the sample. We therefore collected information on velocity of onset as "quickly," "slowly," or "in between" and used an ex-post classification of water depths as low, intermediate and high. To build up the index, our first step was to calculate the Hazard Rate (HR) as a combination of water depth (WD) and flow velocity (FV).

$$HR=WD\times FV$$

where $WD\in\{1,2,3\}$ and $FV\in\{1,2,3\}$. For water depth, $WD=1$ if the maximum water depth reported by the individual is lower than 10 cm, $WD=2$ if the maximum water depth is between 10 and 80 cm and $WD=3$ if the maximum water depth is more than 80 cm. As for flow velocity, $FV=1$ if the floodwaters rise slowly according to the responder, $FV=3$ if the floodwaters rise quickly and $FV=2$ if the responder reports that the floodwater rise somewhere between slowly and quickly. Therefore, $HR\in\{1,2,3,4,6,9\}$, as shown in the hazard matrix in Table 1.

Table 1. Hazard Rate Class Matrix[a]

WD \ FV	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9

Legend: WD: water depth, FV: flow velocity
Low (1) Moderate (2, 3, 4) Significant (6, 9)

[a]Source: own elaboration.

As a second step, we construct three flood hazard classes: Class 1 (Low Hazard) if $HR=1$, Class 2 (Moderate Hazard) if $HR\in\{2,3,4\}$, and Class 3 (Significant Hazard) if $HR\in\{6,9\}$.

3. Results

The deterioration of health measured by a positive change between the GHQ-12 score at the worst time of the

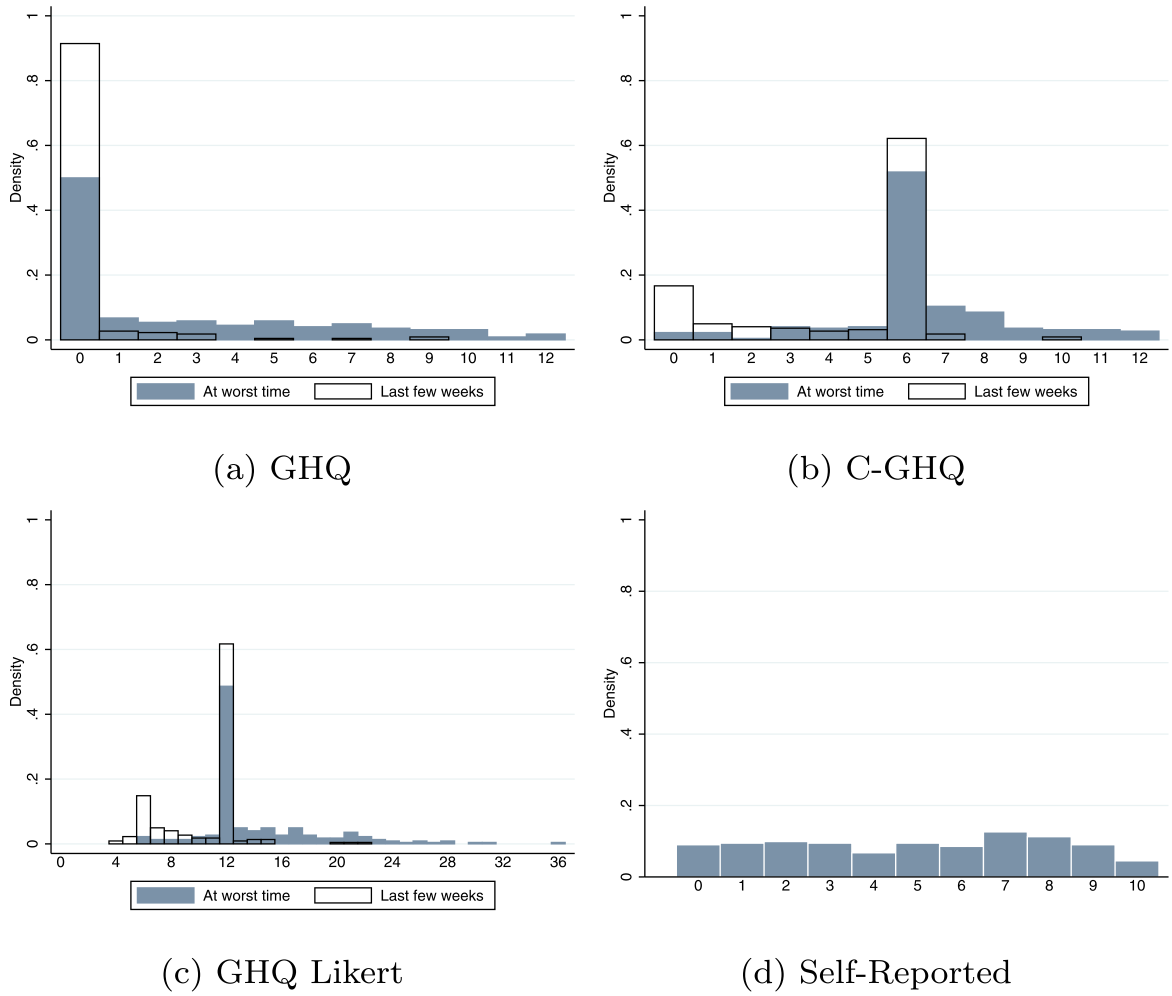

Figure 1. Histograms of GHQ-12 scores at the worst time of the flood and over the past few weeks and of self-reported scores. Blue bars in Figures 1a–1c represent the health scores at the worst time of the flood. White bars represent the health scores in the last few weeks before in the interview.

flood and the GHQ-12 of reference and by the self-reported impact reveals an effective deterioration in this sample (Figure 1); the histograms of GHQ-12 scores shift toward the highest scores and the self-reported scores include several nonzero cases. Health scores are internally consistent as measured by the Cronbach's alpha coefficient of 0.86 found for both the GHQ-base and the GHQ-worst.

3.1. A Unidimensional Diagnostic of Mental Health Drivers

We analyze individually the factors liable to affect individuals' mental health deterioration due to flooding. These factors refer to the characterization of the hazard, the potential damage, flood experience, and prevention of flood losses.

3.1.1. Hazard Rate Class Index

We measure the severity of floods in a hazard rate class index that combines water depth and flow velocity as indicated in section 2.2. Table 2 shows average data for the different health scores (GHQ deterioration, C-GHQ deterioration, Likert deterioration, and self-reported impact) for each hazard rate class index (low, moderate, and significant). Observe that the higher the Hazard Rate is, the higher the mental health degradation scores are. As expected, there is a positive relationship between the severity of flooding and mental health deterioration (Appendix Table B1 shows the statistical tests of differences between categorical variables). It should be noted, however, that 77% of responders report a significant hazard flood event while only 2% report a low hazard flood event. In addition, those reporting a low hazard show no deterioration in the GHQ-12 in any of the three scores.

Table 2. Hazard Rate Class Index and Health Scores

	Hazard Rate Class Index		
	1-Low	2-Moderate	3-Significant
GHQ deterioration	0.0	1.7	2.5
C-GHQ deterioration	0.0	1.4	2.0
Likert deterioration	0.0	2.4	4.0
Self-reported impact	3.3	3.7	5.2
Responders	2%	21%	77%

3.1.2. Prevention

Other important determinants that may influence the prevalence of symptoms of mental health problems after flood events are those related to preparedness and flood control [*Paranjothy et al.*, 2011; *Shultz et al.*, 2013]. *Shultz et al.* [2013] refer to these factors as disaster stressors that can act in the preimpact phase, in the impact phase, or in the postimpact phase. We consider two factors, one in the preimpact phase (flood warning) and the other in the postimpact phase (insurance against flooding). The stressors in the impact phase are those related to flood hazards considered above.

We collected data from the survey on whether the responder received a *flood warning* from any source before the flood. As can be observed in Table 3, 75% of responders received no such warning. In addition, the average scores for mental health deterioration increase slightly when respondents did receive a flood warning. Therefore, this factor seems to act as a disaster stressor, increasing mental health disorders.

On the other hand, the postimpact phase is related to response, recovery, and reconstruction after flooding [*Lamond et al.*, 2015]. In these phases, flood insurance is considered as an important stressor. *Paranjothy et al.* [2011] mention "problems with insurer" as a major predictor of psychological distress. Dealing with insurance claims has been found to be one of the most significant factors affecting people's psychological health in various UK studies [*Tapsell*, 2009; *Tunstall et al.*, 2006]. In our data base, 51% of the respondents had flood insurance when they suffered their worst flood. Moreover, there is a clear increase in the scores of mental health deterioration for those who had flood insurance, as can be seen in Table 3. Problems with insurers in the postimpact phase seem to be an important disaster stressor.

In regard to preparedness, flood risk appraisal is an element that favors prevention and motivates protection against flooding [*Grothmann and Reusswig*, 2006; *Richert et al.*, 2017]. According to the data in Table 3, 53% of respondents reported that they were aware of flood risk in the area before they were flooded. That awareness decreases the different health scores.

3.1.3. Time Effect and Flood Experience

With regard to household experience, those that have experienced floods before may know how to react to further flooding and how to recover and return to their day-to-day life after a flood. *Alderman et al.* [2012] report different health problems related to flood events, in both the short and long run, and identify previous flood experience and disaster preparedness as one of the factors that may influence the development of such health disorders. Given that we are comparing current health status and health status after the worst flood, our data only show whether flood experience affects memories of the worst flood event. For those who reported more than one previous flood experience, our data do not enable us to know whether their worst flood was their first or a subsequent one. However, to capture a flood experience effect, we distinguish between those respondents who report their worst flood before 2010 (pre-2010) and after 2010 (post-2010). For respondents with previous flood experience, we consider that those who report their worst flood event after 2010 are more likely to have had flood experience before the worst flood.

Table 4 shows that post-2010 subjects report better health scores (i.e., less deterioration of mental distress scores) than pre-2010 subjects with previous flood experience for all the health scores considered. Also, respondents with no previous flood experience show greater mental health deterioration when their worst

Table 3. Preparedness and Health Scores

	Flood Warning		Insurance		Awareness	
	No	Yes	No	Yes	No	Yes
GHQ deterioration	2.2	2.6	1.2	3.4	2.9	1.8
C-GHQ deterioration	1.7	2.3	0.8	2.9	2.4	1.3
Likert deterioration	3.4	4.3	1.7	5.4	4.8	2.6
Self-reported impact	4.8	5.1	4.7	5.1	4.9	4.9
Respondents	75%	25%	49%	51%	47%	53%

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Table 4. Flood Experience and Health Scores

	Without Flood Experience		With Flood Experience	
	Pre-2010	Post-2010	Pre-2010	Post-2010
GHQ deterioration	1.7	2.1	3.2	1.9
C-GHQ deterioration	1.3	1.8	2.6	1.5
Likert deterioration	2.3	3.5	5.2	2.7
Self-reported impact	4.7	4.4	5.5	4.4
Respondents	36%	22%	28%	14%

flood event occurred in the recent past (post-2010), except in self-reported scores. Flood experience thus seems to reduce mental distress from flooding when the flood occurred in the recent past.

3.1.4. Damage

Other important factors that have been considered in the literature are those related to the damage suffered by households during the flooding event. For example, *Sekulova and van den Bergh* [2016] conduct a survey on life satisfaction on individuals who have experienced floods and their results show that material and psychological damage significantly reduce subjective well-being.

In our case, we distinguish the possible effect on mental health scores of (i) structural damage and/or damage to household contents, which we refer to as *material damage;* (ii) physical health effects during or after flooding, which we call *physical damage*; and (iii) loss of irreplaceable items of sentimental value, referred to here as *intangible damage*.

Physical damage is reported by slightly less than 14% of respondents and intangible damage by slightly more than 13%. The proportion who report material damage is higher at 33% of the respondents. In any event, suffering material, physical, or intangible damage has a negative effect on mental health scores: as can be seen in Table 5, health scores increase when there is damage of any kind. It is worth mentioning, however, that the average health scores are worse for those reporting physical or intangible damage than for those reporting material damage.

3.2. A Multidimensional Diagnostic of Mental Health Drivers

The statistical analysis shown above reveals that unidimensionally, variables of flood hazard, prevention, time, and experience discriminate the prevalence of flood-related mental distress. These variables place respondents in a category that helps us to apprehend how much distress an individual experiences because of floods. However, in addition to individual factors the level of distress is also the result of a combination of several socio-cultural factors [*Davydov et al*., 2010]. A regression analysis accounts for the multidimensionality of the factors explaining mental health distress. We tested the effect of several exogenous variables on health scores. The final model is shown in Table 6. Other socio-economic variables such as gender, age, and family size were found to have no significant impact on mental health above a 90% level of confidence. Income is poorly referenced in the database. Nor did proxies for income such as the number of cars or home ownership have any significant impact. A literature review by *Fernandez et al*. [2015] shows no consensus on the direction and significance of the effect of socio-economic variables on health outcomes.

Results from Table 6 reveal a significant impact of the severity of the floods measured by the Hazard Rate Class Index. Higher levels of mental health degradation are thus likely to be observed in places where both flow velocity and water depth are greater. Our result suggests then that flow velocity also produces stress in people in association with water depth, whereas preceding studies focused solely on water depth [*Lamond et al*., 2015; *Paranjothy et al*., 2011; *Tunstall et al*., 2006]. The worry caused by flow velocity even appears as the third most worrying flood factor for people in this sample when respondents were asked to select the most worrying factors from among duration, depth, dirtiness, speed/flow, time of day, season of

Table 5. Damage and Health Scores

	Material Damage		Physical Damage		Intangible Damage	
	No	Yes	No	Yes	No	Yes
GHQ deterioration	1.9	3.2	2.0	4.2	2.1	4.1
C-GHQ deterioration	1.5	2.5	1.7	2.9	1.7	3.1
Likert deterioration	2.8	5.1	3.1	6.9	3.1	6.8
Self-reported impact	4.1	6.4	4.4	7.6	4.5	7.6
Respondents	67%	33%	864%	14%	87%	13%

Table 6. Marginal Effects of the Determinants of Health Scores[a]

	Self-Reported	GHQ	C-GHQ	GHQ Likert
Hazard rate class index	1.00[b]	0.25	0.04	0.65
Flood experiences	0.04	0.08[c]	0.05[d]	0.11[c]
Post-2010	−0.86[c]	−1.06[b]	−0.90[b]	−1.54[b]
Insurance	0.44	2.60[b]	2.49[b]	4.20[b]
Awareness	0.09	−1.06[b]	−0.95[b]	−1.97[b]
Flood warning	0.21	−0.07	0.32	0.34
Material damage	0.87[d]	0.27	0.16	0.29
Physical damage	2.26[b]	2.18[b]	1.60[b]	3.78[b]
Intangible damage	1.68[b]	0.69	0.46	1.15
Log likelihood	−611.9	−556.1	−465.1	−714.2
AIC	5.602	5.100	4.280	6.524
BIC	−394.4	−316.5	−484.8	−97.82
Observations	222	222	222	222

[a]Note: Coefficients show the marginal effect of exogenous variables on mental health deterioration scores, i.e., the effect on the expected number of "yes" answers on the score scale given a one unit increase in the explanatory variable.
[b]*P*-value <0.01.
[c]*P*-value <0.05
[d]*P*-value <0.1.

year, warning time, and others (the top three factors are water depth (38%), duration (21%), and speed/flow (16%)).

Preimpact prevention factors such as flood risk *awareness* have an econometrically significant impact on mental health deterioration. Respondents aware that their house is located in a flood-prone area are expected to have mental health distress degradation scores which are lower by between 1 and 2 points (−0.95 to −1.97) than those of respondents unaware of the risk. *Flood warning* has no econometrically significant effect on mental health deterioration. Even with a positive sign of the coefficient associated to flood warning, alerts can be perceived as a stressor for people who have been flooded as they signal the onset of flood consequences. This nonsignificance and positive sign could reveal deficiencies in alert systems as regards changing people's behavior from the fatalism of an alert to coping with the flood [*Parker and Priest*, 2012].

In the aftermath of flooding, recovery is closely linked with dealing with insurance claims. However, our results show that respondents with *insurance* are expected to suffer more mental health distress: their mental health degradation scores is expected to be higher by 2.5–4 points than those of noninsured people. Having insurance proves to be a major source of stress for flood victims. This sounds counter-intuitive since having insurance might be expected to result in less distress as the material consequences of the flood are covered. However, the uncertainty relative to the level of compensation that results from claims could also be a source of distress for insured parties, and problems with insurers are frequently noted as a stress generator in the literature [*Carroll et al*., 2010; *Paranjothy et al*., 2011; *Tunstall et al*., 2006].

The accumulation of *flood experience* over people's lifetimes significantly degrades psychological health, although the expected effects are relatively small: mental health degradation is expected to increase by between 0.05 and 0.11 points. Living in places where floods occur more frequently means that people are more exposed to stress-generating situations and in this sample 75% of the people had experienced up to 3 flood events in their life time. However, from the negative sign of the coefficient associated with the variable post-2010 in Table 6, it can be deduced that people flooded in recent years are expected to suffer levels of distress around 1 point lower (between 0.8 and 1.5) than people flooded in a more distant past. We rule out the severity of the hazard as a cause of this effect, as we found no significant difference in the *Hazard Rate Class Index* before and after 2010. However, we did find differences in health scores with flood experience before and after 2010 (Table 4 and Appendix Table B1).

Material, physical, and intangible damage suffered from flooding significantly degrades mental health. Results show that physical damage is the main source of distress among damage types. Respondents who have experienced any physical injury during flooding are expected to suffer more distress than those who have not. This factor is expected to add between 1.6 and 3.8 points to their mental health deterioration scores. Intangible damage suffered is the second biggest source of damage-related distress: mental health degradation is likely to be 1.7 points greater when the respondent has lost intangible goods. Last, material damage would increase the distress score by 0.8 points. Physical health damage and intangible losses thus outweigh financial losses when explaining mental distress from flooding. Indeed, material damage can be offset by insurance whereas intangible damage is the loss of irreplaceable goods with sentimental value. Social intangible losses are often greater than financial losses [*Penning-Rowsell and Green*, 2000; *Tapsell*, 2009]. Similar results are found by *Thieken et al*. [2016] for the case of the June 2013 floods in Germany. They find that mental health impacts are perceived by flood affected residents as more serious than financial losses.

4. Discussion: Building Resilience

The multidimensional econometric analysis identified a number of relevant factors for understanding the effect of floods on well-being. We now discuss them in term of how developing collective and individual resilience to flooding could help to maintain relatively stable and healthy levels of psychological functioning, known as human resilience, as defined by *Bonanno* [2004], and make societies or communities better prepared. Human and community resilience are interconnected in the sense that a society or a community often develops prevention measures that enhance human resilience [*Castleden et al*., 2011].

Flood resilience arises from adapting to the variability and uncertainty that are always inherent in flooding events. These features are exacerbated by climate change, with a more unstable hydrological cycle [*Associated Programme on Flood Management*, 2012]. If it is assumed that periodic flooding is inherent in environmental dynamics then adaptation and resilience are essential in flood management [*Liao*, 2012]. Flood prevention based on flood-control infrastructure need not be the only objective of flood management: enhancing the resilience of cities, populations, and natural environments to flood risks is also a well-being improving management of the risk [*Associated Programme on Flood Management*, 2012; *Liao*, 2012; *O'Neill et al*., 2016]. Autonomous and soft adaptation options have a major role to play in this. We discuss how public information on flood risks could influence both awareness and risk prevention, how flood warnings could contribute to the ability to accommodate flooding, how flood experience helps to adjust coping capacities, and how the role of insurance could influence recovery from flooding, especially psychological recovery.

4.1. Public Information on Flood Risk

The econometric analysis indicates that the psychological deterioration is lower for those who are aware that their houses are located in flood-prone areas. In most developed countries there are complete, accurate flood risk maps that identify flood-prone areas and classify them according to their return period. However, our sample reveals a gap in information sources. Individuals obtained their information on flood risk by deduction ("proximity to the river" was reported as a source of information), from peers and local communities rather than from the media or from official institutions. Providing citizens with effective access to this information in a language and format that can be understood by the general public would reduce this gap between information sources. The developing of individual awareness of flood risk on the part of both institutions and local communities [*Parker and Handmer*, 1998] can significantly improve awareness and thus, as suggested by our results, reduce the psychological deterioration associated with flooding. However, the literature has shown that people living in areas prone to natural hazards often do very little to lessen their risk [*Grothmann and Reusswig*, 2006]. People sometimes do not perceive the severity of the threat (threat appraisal) or feel that self-prevention behavior is not effective (coping appraisal) or can be replaced by public prevention (reliance on public flood protection). Therefore, providing support and guidance on what to do as preventive and recovery measures would help to improve the efficiency of flood risk management. Flood risk maps, depicting flood-prone areas, evacuation routes, and safe shelters can play a critical role in awareness building [*Associated Programme on Flood Management*, 2012], particularly when people lack flood experience. However, the results of our analysis also provide some additional insights on this as developed below.

4.2. Developing Floodability

Households living in flood-prone areas should develop a certain floodability, i.e., the physical ability to accommodate flooding, as an element of resilience [*Liao*, 2012]. This floodability at household scale targets reductions in the material, physical, and intangible damage associated with flooding. Our econometric results suggest that this would reduce the impact of flooding on psychological well-being. Developing floodability by taking private mitigation measures, such as adapting the structure of the home to floods, can be highly influential. *Poussin et al*. [2015] report examples of public/private measures to adapt the structure of homes to floods: locating power sockets above the most likely flood level on the ground floor, placing electronic devices on upper floors, keeping sandbags or other water barriers in the household, etc. Some of these measures can be relatively costly or technically difficult to implement on existing properties; however, they could be considered in new properties and in properties to be refurnished. As for the intangible damage, not keeping irreplaceable items or goods with sentimental value on the ground floor may be advisable. A possible way of diffusion of such recommendations in addition to evacuation routes and safe shelters could be to supplement public flood risk maps, at the catchment scale.

An effective public education campaign can empower individuals and families to identify and carry out long-term strategies against flooding [*Associated Programme on Flood Management*, 2012; *Girons Lopez et al.*, 2016] and influence how people behave in response to hazard warnings. Lead time is a key element in preventing damage [*Priest et al.*, 2011; *Thieken et al.*, 2005]: the earlier the warning is given the longer households have to prevent potential damage. In our sample, evidence of the lack of education-and-preparedness for flooding can be found in the fact that fewer than one percent of respondents identified lead time as a worrying flood hazard factor, only a quarter of them received any flood warning and for half of them the lead time was less than 5 h. Broadening the warning system to include online information and social networks/media could improve both its scope and its timing, as online information also helps to improve preparedness and reduce losses [*Allaire*, 2016]. Experience can help in the development of these strategies.

4.3. Learning From Flooding

In resilience-based flood hazard management, periodic floods are learning opportunities [*Liao*, 2012]. Our results suggest that repeated flood experience in the recent past leads to less distress in people. Indeed, as individual memories of floods and their consequences remain, people are prone to adapt their attitude toward the risk [*Burn*, 1999; *Viglione et al.*, 2014]. Thus, living in a flood risk area means suffering some flooding, and that experience should be used to build the ability to reorganize. *Liao* [2012] points out that each flood experience creates a chance to adjust internal structures and processes and to build knowledge and develop coping strategies. This approach implies an evaluation and update of public flood hazard maps. Currently, flood hazard maps are updated as a result of new hydraulic studies or new climate change scenarios that modify, expand, or reduce flood-prone areas. Learning from flooding means updating these maps to include new recommendations for flood adaptation and enhance existing ones.

4.4. Recovering From Flooding

One of the main determinants of psychological deterioration arises in the post-impact phase, in the role of insurance. Flood insurance is necessary in flood-prone areas to cover damage. However, the data show that just half of the respondents report having flood insurance. A similar lack of coverage is found in other countries such as the United States and Germany [*Michel-Kerjan and Kunreuther*, 2011]. These authors propose a redesign of flood insurance in order to increase coverage. However, that redesign does not consider the stressful process of dealing with insurance companies after flooding. Handling the damage appraisal and seeking compensation is a complicated process that causes distress. *Carroll et al.* [2010] provide a qualitative assessment of potential conflicts with insurance companies. People are not always sure of their policy coverage and entitlements, complain of a lack of clarity in the procedures, lack experience in making large claims or misunderstand the role of loss adjusters, among other problems. Delays and uncertainty in the resolution and payment of compensation also increase distress, regardless of whether the compensation mechanism is private or public. A redesign of flood insurance aimed at reducing these multiple uncertainties would reduce mental distress in people and make the recovery process more effective.

5. Limitations

Learning processes, information, and communication foster community resilience as do economic development and social capital [*Norris et al.*, 2008]. As part of the community, individuals build and benefit from economic development and social capital in support of their adaptive capacities. In this study, data on economic factors such as income and the cost of measures to improve floodability were difficult to collect and the proxies tested did not have a significant effect on mental health deterioration. Other studies have also reported difficulties in collecting data on the cost of prevention [*Richert et al.*, 2017]. Home ownership is also likely to influence the likelihood of undertaking prevention measures [*Richert et al.*, 2017]. However, there is no evidence that home owners experience higher distress: *Tunstall et al.* [2006] find that renters suffer higher mental health impacts and interpret ownership as a proxy for income that may help households to cope with flood effects. Our sample is mostly composed of home owners, so we are unable to make any inferences on the role of ownership. In addition to economic factors, factors related to social capital must be taken into consideration in understanding the drivers of resilience. Some of these factors, such as ethnicity, are tied to the area studied. Different ethnic groups develop particular social networks that can enhance or disrupt community resilience [*Tobin*, 1999]. The role of ethnicity has not been addressed in this study as foreign communities in the case study area are mostly concentrated in large cities, so any ethnic effect measured could have been a city size effect.

The reporting of data from past flood events can affect the quality of the data. Recollections of distant events can lead to misperceptions in some variables, especially mental health scores and hazard factors. However, we have sought to minimize this limitation by considering changes in well-being rather than clinical caseness, i.e., focusing on the variation in GHQ scores between the worst time of the flood and the few weeks before the interview (the GHQ in the last few weeks before the interview was first conducted). Unexpectedly, 25 cases (8.3% of the sample) showed a negative difference score that implied an improvement in health status with flooding. Most of them showed difference scores of -1 or -2. Given the closeness to zero of the difference scores and the small number of cases, we have treated these cases as inconsistencies and cases where other factors may play a role. With regard to flood hazard, the measurement error is corrected by constructing the hazard rate class index. These limitations suggest that our findings should be interpreted with caution.

6. Conclusions

A major component of resilience is the ability of individuals and societies to cope with the stress generated by extreme events such as floods. This paper seeks to contribute to the understanding the determinants of mental resilience to flooding in both individual and collective terms. The analysis captures potential subjective degradation in well-being to report the early stages of psychological distress and build up individual and social responses to flooding.

Our measure of mental health degradation after flooding is based on both event-specific and nonevent-specific indicators: a self-reported question on health status and the GHQ-12 General Health Questionnaire. We use an econometric approach to account for the multiplicity of mental health determinants.

Our results place new emphasis on the role of flood hazard, more particularly of flow velocity, on mental health degradation and provide resilience building elements for reducing the degradation in well-being from flooding. We show that flow velocity in combination with water depth is an important stressor for people who have experienced flood events. An innovative way of combining these two factors is proposed: the so-called Hazard Rate Classification Matrix. Building up resilience to the stress caused by flood events among communities and individuals can be a very reasonable no-regret alternative for public adaptation that triggers a number of private and autonomous adaptation practices.

Building on our results, we highlight behaviors that enhance mental resilience in both human and community dimensions. Indeed, psychological distress can be managed in several ways, such as the following:

i. Coordinating the dissemination of efficient public information on flood risks and flood protection and prevention behaviors. This information should deal with not only risks but also the type of measures that individuals and communities can adopt to reduce impacts and increase flood resilience.
ii. Developing protection capabilities to reduce physical, intangible, and material damage. This can be achieved through conventional measures that can be implemented by public administrations, such as good building practices (or codes) to increase resilience of homes and buildings and designing operative early warning systems. Note that flood warnings also generate stress for those who receive them. A warning system should thus also enhance the ability to cope with the stress by proposing a number of soft adaptation options that citizens can autonomously adopt, especially regarding physical and intangible damage.
iii. Designing insurance procedures for faster recovery. This should also include a post-disaster claims protocol to reduce the significant stress that the whole claims procedure may generate. According to our results, this is a clear no-regret alternative that could greatly ameliorate post-traumatic stress management.

iv. Learning from one's own experience and from that of others may play an important role in increasing mental resilience to flood events. In this regard, memories stimulate future adaptation to flooding.

Appendix A: Statistics and Correlation of the Self-Reported Flood-Specific Items

Appendix A presents the different health score questions: the General Health Questionnaire GHQ-12 (Table A1) and the self-reported questions (Table A2).

Table A1. The GHQ-12 General Health Questionnaire

	Label	Framing
1	Been able to concentrate on whatever you're doing	Positive
2	Lost much sleep over worry	Negative
3	Felt you were playing a useful part in things	Positive
4	Felt capable of making decisions about things	Positive
5	Felt constantly under strain	Negative
6	Felt that you couldn't overcome difficulties	Negative
7	Been able to enjoy your normal day-to-day activities	Positive
8	Been able to face up to your problems	Positive
9	Been feeling unhappy and depressed	Negative
10	Been losing confidence in yourself	Negative
11	Been thinking of yourself as a worthless person	Negative
12	Been feeling reasonably happy, all things considered	Positive

Table A2. Statistics and Cross-Correlation of Self-Reported Impact of Floods

	Label	Percent	Mean	Median	Standard Deviation
A	Effect upon your health	93	1.6	0	2.5
B	Having to leave home	70	1.5	0	3.2
C	Damage to replaceable furniture	77	2.5	0	3.6
D	Worry about flooding in the future	96	5.2	5	3.3
E	Loss of irreplaceable objects	73	1.4	0	3.1
F	All problems and discomfort from house recovery	93	4.5	4	3.3
G	Damage to the house itself	83	3.3	2	3.2
H	Stress of the flood event itself	97	4.4	5	3.3
I	Problems with insurers/loss adjusters	61	1.1	0	2.5
J	Problems dealing with builders	58	0.6	0	2.2
K	Loss of or distress to pets	66	0.5	0	2.0
L	Loss of house value	75	1.6	0	2.9
	General effect upon the household	100	4.9	5	3

Scale of self-reported items: 0 to 10.

	A	B	C	D	E	F	G	H	I	J	K	L
A	1											
B	0.56[a]	1										
C	0.52[a]	0.61[a]	1									
D	0.50[a]	0.36[a]	0.54[a]	1								
E	0.46[a]	0.65[a]	0.70[a]	0.38[a]	1							
F	0.55[a]	0.58[a]	0.69[a]	0.60[a]	0.58[a]	1						
G	0.54[a]	0.48[a]	0.64[a]	0.57[a]	0.51[a]	0.66[a]	1					
H	0.69[a]	0.52[a]	0.58[a]	0.67[a]	0.53[a]	0.69[a]	0.60[a]	1				
I	0.33[a]	0.26[a]	0.49[a]	0.40[a]	0.32[a]	0.45[a]	0.41[a]	0.47[a]	1			
J	0.37[a]	0.20[a]	0.13	0.36[a]	0.15	0.25[a]	0.43[a]	0.40[a]	0.67[a]	1		
K	0.33[a]	0.41[a]	0.37[a]	0.22[a]	0.35[a]	0.37[a]	0.22[a]	0.31[a]	0.32[a]	−0.04	1	
L	0.60[a]	0.54[a]	0.58[a]	0.50[a]	0.55[a]	0.55[a]	0.63[a]	0.66[a]	0.37[a]	0.53[a]	0.45[a]	1

[a]Significant with a 95% confidence level.

Appendix B: Health Group Tests by Groups

Appendix B presents the statistical tests of difference for categorical variables. It tests whether the difference in health scores is significantly different between the groups of the categorical variables (Table B1)

Table B1. Statistical Test of Health Scores by Groups

Categorical Variables	Statistic	General Effect	GHQ	C-GHQ	GHQ Likert
Hazard rate class index[a]	Test statistic	11.300	5.020	3.800	5.900
	P-value	0.003	0.080	0.140	0.050
Post-2010[b] with flood experience	Test statistic	1.938	1.779	1.540	1.861
	P-value	0.052	0.075	0.123	0.062
Post-2010[b] without flood experience	Test statistic	0.498	−0.261	−4.039	−3.535
	P-value	0.618	0.794	0.000	0.000
Insurance[b]	Test statistic	−1.070	−5.040	−6.200	−5.600
	P-value	0.280	0.000	0.000	0.000
Awareness[b]	Test statistic	0.080	2.600	2.600	3.040
	P-value	0.930	0.070	0.009	0.002
Flood warning[b]	Test statistic	−0.700	−0.900	−1.690	−1.600
	P-value	0.440	0.330	0.090	0.100
Material damage[b]	Test statistic	−5.200	−3.140	−2.700	3.030
	P-value	0.000	0.001	0.006	0.002
Physical damage[b]	Test statistic	−5.700	−4.200	−3.600	−4.300
	P-value	0.000	0.000	0.000	0.000
Intangible damage[b]	Test statistic	−5.270	−3.200	−2.600	−3.150
	P-value	0.000	0.001	0.008	0.001

[a]Based on the Kruskal-Wallis test.
[b]Based on the Wilcoxon rank test.

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