Geoenvironmental Disasters

RESEARCH

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Individuals' perceptions of areas exposed to coastal flooding in four French coastal municipalities: the contribution of sketch mapping

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Abstract

Background: This study analyzes individuals' perceptions of areas exposed to coastal flooding at a local level using sketch mapping methodology. In this way, 318 individuals were surveyed in four coastal municipalities in France (Barneville-Carteret, Saintes-Maries-de-la-mer, Châtelaillon-Plage and Sainte-Anne). We assessed the disagreement between expert estimates and individuals' perceptions of areas exposed to coastal flooding using sketch mapping indicators. We also determined the relationships between individuals' living environments and the way they perceived the spatial extent of coastal flooding.

Results: Respondents were likely to under-assess the exposure of areas that are actually exposed according to expert hazard maps. Perceived distance to coastal flooding areas appeared to be a predominant factor in assessing individuals' perceptions.

Conclusions: Local preventive actions could take into account the individuals' tendency to under-estimate the areas exposed to coastal flooding. Individual perception of the spatial extent of coastal flooding appeared to be more influenced by the perceived distance of the home to exposed areas than the objective distance. It is a result that raises the question about the individuals' understanding of hazard maps and regulatory maps. This may necessitate the improvement of the appropriation of these documents by the inhabitants by involving them more closely in the application and decision process that directly concerns.

Keywords: Risk perception, Coastal flood risk, Sketch maps, Hazard proximity

Background

Coastal flooding represents a major risk taking into account the human, environmental and economic losses it can potentially inflict, particularly in highly populated coastal areas (McGranahan et al. 2007; Small and Nicholls 2003). The risk of coastal flooding is expected to increase (Nicholls and Cazenave 2010) considering the sea level rise (Church and White 2006; IPCC 2014), the expected increases in coastal populations (Lutz and Samir 2010; Nicholls 2004) and the concentration of stakes in coastal areas (Meur-Férec et al., 2008; Michael, 2007). According to Nicholls (2011) and Nicholls and Cazenave (2010), 200 millions of people are vulnerable to coastal flooding during temporary extreme sea level events. McGranahan et al. (2007) determined that the low elevation coastal zones (up to ten meters elevation) represent 2% of the world's land and has 10% of the global population (around 600 million people). More specifically, deltas are the most vulnerable areas to coastal flood risk mostly because of their subsidence (Chaumillon et al. 2017) caused by tectonics, compaction, sedimentation and anthropogenic factors (Brown and Nicholls 2015). The Bay of Bengal is the most vulnerable region in the world to coastal flooding induced by hurricanes (Breilh et al. 2013). Thus, in 1970 between a quarter to half a million people died during cyclone Bhola (Hossain 2018). In 2008, cyclone Nargis caused the death

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of 130,000 people in Myanmar (Wolf 2009). The Gulf of Mexico figures among the most vulnerable regions in the world to coastal flooding. In 2005, hurricane Katrina resulted in more than 1500 deaths and 84 billion dollars in damages (Blake et al. 2007). More recently, typhoon Haiyan, which hit the Philippines, led to the death of 6000 people and to damages estimated at 802 million dollars (Mori et al. 2014).

In France, the last major flood event was associated to storm Xynthia during the night of February 27th and 28th, 2010. More than 50,000 ha of land were flooded, and 55 towns were affected by flooding on the Atlantic coast. During this tragic event, 47 people died including 41 by drowning (Breilh et al. 2014; Chadenas et al. 2014; Chaumillon et al. 2017; Creach et al. 2015; Kolen et al. 2010; Vinet et al. 2012). The storm also caused 2.5 billion euros of flood damage (Creach et al. 2015; Lumbroso et al. 2011). More recently, French overseas territories in the Antilles region experienced several cyclones and tropical depressions in 2017. Irma, one of the major cyclones of the 2017 cyclonic season, caused coastal flooding in Saint Barthelemy and Saint Martin on the 6th of September.

This research paper is driven by the fact that coastal flooding represents an increasing major risk in the world including French coastal areas. We aim to complement the multiple research about coastal flooding by analyzing the public perception of coastal flood risks in French coastal areas. Thus, we compare expert estimates and individuals' perceptions of areas exposed to coastal flooding at local level.

According to Slovic (1987), "studies of risk perception examine the judgments people make when they are asked to characterize and evaluate hazardous activities and technologies". Thus an individual's perception could be different from expert assessment of hazard or risk for many reasons including the difficulties of assessing probabilities of hazard, because of a lack of information about the risk (Botzen et al. 2009; Heitz and Shimabuku 2017) or because a lack of confidence in the authorities (Goeldner-Gianella et al. 2017). Individuals' perception of risk has been widely studied using different methodologies of surveys. Many studies have analyzed coastal flood risk perception using questionnaires (Boyer-Villemaire et al. 2014; Combest-Friedman et al. 2012; Costas et al. 2015; Koerth et al. 2013; Lieske et al. 2014; Schmidt et al. 2014) In addition to questionnaires, several studies have also analyzed individuals' perceptions of the spatial extent of risk or hazard using methodologies from cognitive mapping research such as mental maps, representation maps or sketch maps.

Sketch maps

Downs and Stea (1973) defined cognitive mapping as "a construct which encompasses those cognitive processes which enable people to acquire, code, store, recall and manipulate information about the nature of their spatial environment". Cognitive mapping emerged from behavioral research (Gould and White 1973; Lynch 1960) which considers the spatial dimension of individuals' perceptions and behaviors. This interest led to the emergence of new methodologies of data collecting and thus, new types of data (Golledge 2008). In this way, maps or sketches were used to collect individuals' spatial perceptions of their environment. For example, studies used sketch maps to analyze individuals 'perceptions of neighborhood boundaries (Campbell et al. 2009; Coulton et al. 2013), to investigate individuals' perceptions of crime and fear (Curtis 2012; Curtis et al. 2014; Matei et al., 2001; Matei and Ball-Rokeach 2005). Sketch maps were also used to study the changing perceptions of youths after their transition from a university neighborhood to a university campus (Pearsall et al. 2015) or to investigate students' knowledge of libraries (Horan 1999) Several studies about individuals' perceptions of natural hazards have also used sketch maps. Thus, they have been used to capture individuals' perception of landslide risk (DeChano and Butler, 2001) volcanic risk (Gaillard 2008; Gaillard et al. 2001; Leone and Lesales 2009), flood risk (Brennan et al. 2016; Brilly and Polic 2005; O'Neill, Brennan et al. 2015; O'Neill et al. 2016; Pagneux et al. 2011; Ruin et al. 2007) and coastal flood risk (Cheung et al. 2016). Gueben-Venière (2011), Chevillot-Miot (2017) and Chionne (2018) also used sketch maps during interviews with stakeholders about coastal flood risk.

This study proposes to analyze individuals' sketch maps of areas exposed to coastal flooding from four study sites at a local level. We aimed to assess disagreement between individual and expert estimates of the spatial extent of coastal flooding using several indicators. We assumed there is a relationship between individuals' living environments and the way they perceive the spatial extent of coastal flooding.

Study context

The study took place in four coastal municipalities of France. Barneville-Carteret is a coastal town of 2197 inhabitants (INSEE, 2014) which is located on the West Cotentin coast facing the Channel Sea (Fig. 1). This small town of 10.3 km^2 is exposed to coastal floods both on the sea front and the "Havre de Carteret" (Fig. 2). This geomorphological shape is an inlet locally known "havre" (Robin et al. 2007, 2009) dominated by tidal currents. It is used as a natural harbor. Moreover, Barneville-Carteret is also vulnerable to coastal flooding due to the poor condition of certain dykes located around the "havre" (Mairie de Barneville-Carteret: Digue de la Grève d'Or, unpublished). The 1990 storm

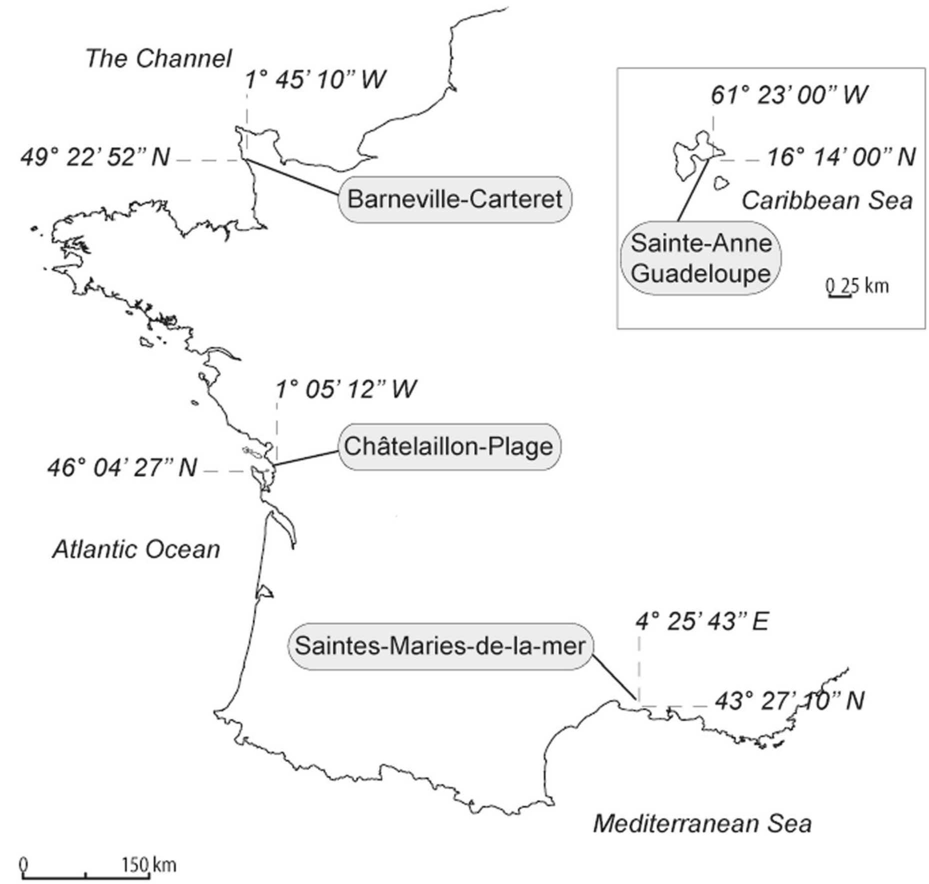

Fig. 1 Location of study sites in France

was the latest biggest and most documented event in this region (DDTM 50 2015) The town also suffered a coastal flood event in 1974, partly caused by the small size and poor condition of the dykes in the "havre". This storm is still present in the memory of respondents.

Saintes-Maries-de-la-mer stretches along the Mediterranean coast (Fig. 1). The town is located in the regional park of Camargue and had 2683 inhabitants in 2014 (INSEE, 2014.). We decided to survey in a delimited zone that stretches 8 km along the seashore and 4.5 km into the hinterland because of the very large surface area of the municipality (374.6 km^2). As can be seen on the map (Fig. 3), most of the respondents lived in the largest urbanized area locally called "the village", which is the center of the town. The remainder of the municipality that we studied consists of lowland areas (marshes and ponds) (Fig. 3). Located in the Rhône delta, the elevation of the village is between 0 m and 2 m above sea level, which makes it highly vulnerable to coastal flooding. This vulnerability is accentuated by the subsidence of the delta. The village is exposed to high waves and strong winds from the SE and SSE which are associated with coastal flooding (Sabatier et al. 2009). They can also generate overflow from marshes and flooding from "Le Petit Rhône", a tributary of the Rhone, by disrupting the normal flow. The center of the village of Saintes-Marie-de-la-mer was flooded during the 1982 storm (DDTM 13 2017).

The third study site is the town of Châtelaillon-Plage, which is located along the Atlantic coast Figs. 1 and 4. This area is mainly composed of lowlands and appears to be the most vulnerable area to coastal flooding on the French Atlantic coast (Breilh et al. 2014). The town suffered from major flooding during the Xynthia storm on the night of February 27th and 28th in 2010, which was the last major coastal flood event in France (Breilh et al. 2013; Chaumillon et al. 2017).

Sainte-Anne is a vast municipality located in the French overseas department of Guadeloupe. It faces the Caribbean Sea on the Atlantic Ocean side (Figs. 1 and 5). Sainte-Anne is exposed to coastal flooding especially from hurricane-induced storm surges. The most recent

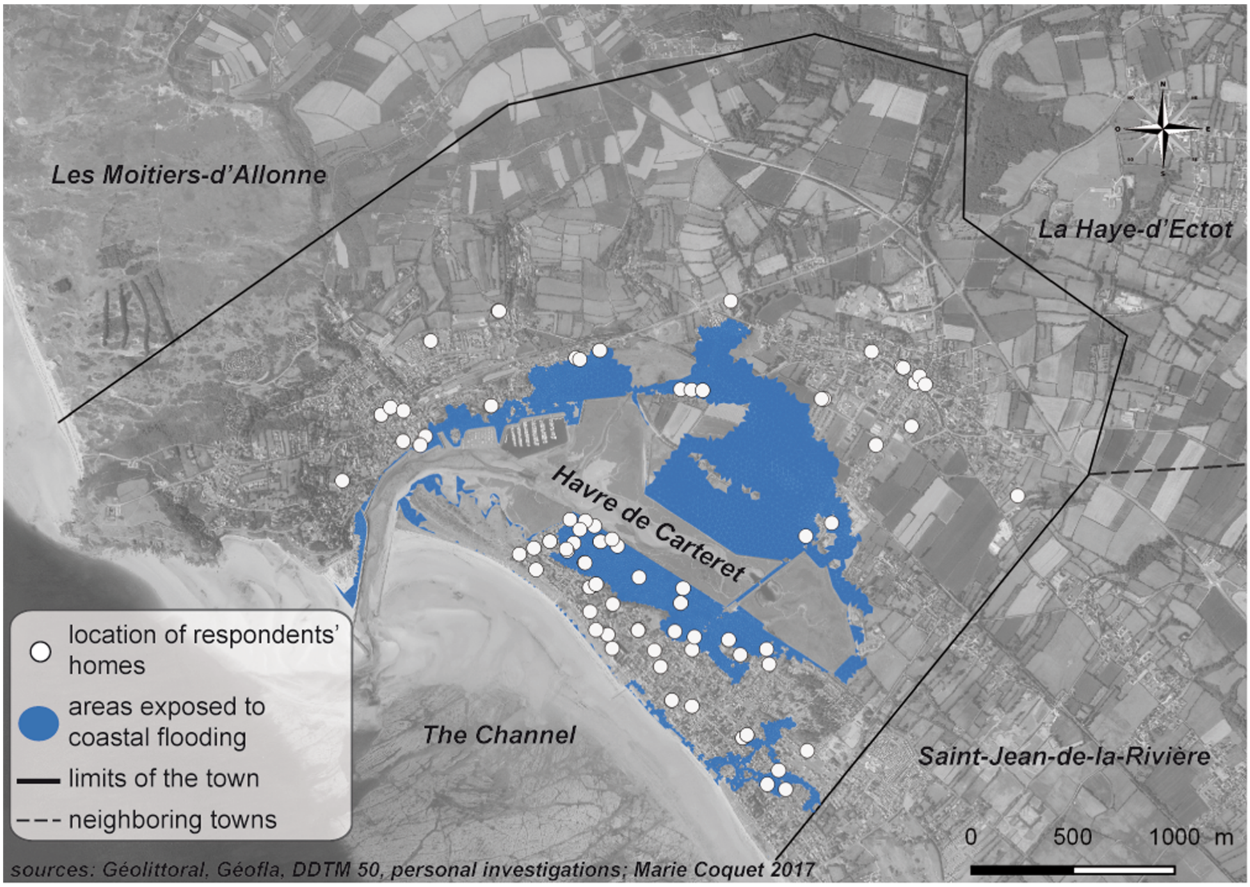

Fig. 2 Location of respondents' homes in the town of Barneville-Carteret

coastal flood event was caused by hurricane Hugo in 1989, which impacted the low-lying areas of Sainte-Anne (Krien et al. 2015).

Methods

Participants

We used convenience sampling for the data collection. We intended to obtain spatial homogeneity of the individuals' location. We also aimed to survey both individuals living in areas exposed to coastal flooding and those who didn't. According to prevention plans, the proportion of areas exposed to coastal flooding differs depending on the study site. This is why the percentage of respondents who lived in those areas varies. Following this methodology of data collection, 318 individuals were surveyed.

In April 2015, we surveyed 92 individuals living in Barneville-Carteret (Fig. 2), 58 of them were women with an average age of 63 and 34 were men with an average age of 59 (Fig. 6). Thirty two individuals lived in areas exposed to coastal flooding, that being 35% of that sample.

Eighty one inhabitants of Saintes-Maries-de-la-mer (Fig. 3) were surveyed in May and October 2015, 43 were women with a mean age of 54 and 38 were men with a mean age of 52 (Fig. 7). Because a very large area of the municipality is exposed to coastal flooding, all the respondents lived in exposed areas.

During June 2015, 77 individuals were surveyed in Châtelaillon-Plage (Fig. 4), 44 of them were women with a mean age of 61 and 33 were men with a mean age of 69 (Fig. 8). Forty four respondents lived in areas exposed to coastal flooding, which corresponds to 57% of the sample.

We surveyed 68 inhabitants in Sainte-Anne in August 2015 (Fig. 5). The sample was composed of 44 women with an average age of 43 years and 24 men with an average age of 45 years (Fig. 9). Six respondents lived in areas exposed to coastal flooding, accounting for 9% of the sample.

Procedures

Data was mostly collected by face to face interviews and some surveys were returned from randomly selected postal addresses. Those returned surveys represented 5.4% of the surveys in Barneville-Carteret, 16% in Saintes-Maries-de-la-mer and 13% in Châtelaillon-Plage. We didn't conduct mail box surveys in Sainte-Anne.

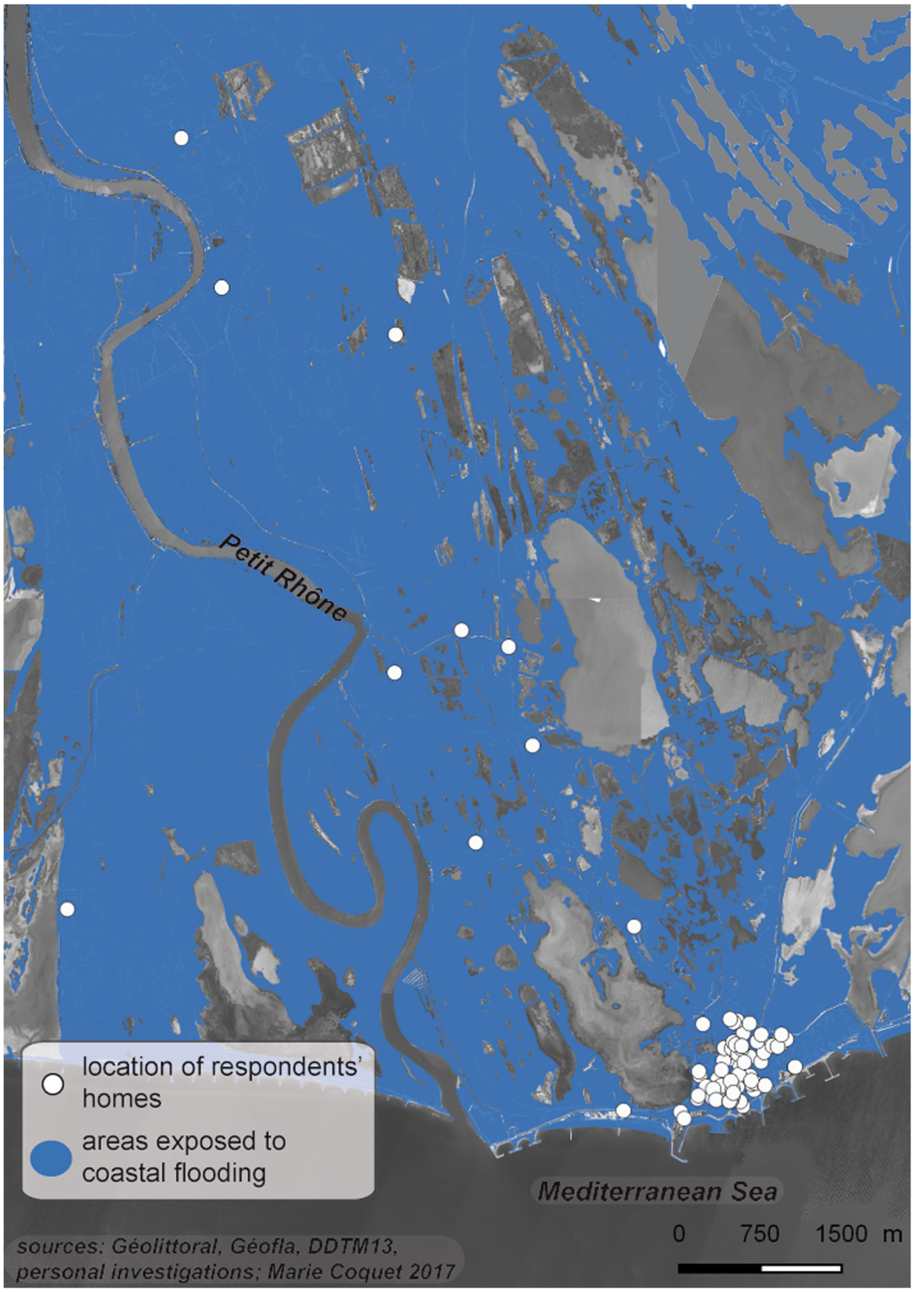

Fig. 3 Location of respondents' homes in the town of Saintes-Maries-de-la-mer. Legend: Most areas which are not considered as exposed to coastal flooding are marshes and ponds

The survey was made up of two parts. In the first part, respondents were asked to sketch areas exposed to coastal flooding on the town scale using a base map following the guideline: "According to you, please represent the areas exposed to coastal flooding in the town of …" We calculated indicators of spatial representation from each individual's map as described in detail in the "Measures" part bellow.

The second part of the survey consisted of 49 questions divided into the following sections: coastal flood risk exposure scale, residence choices, protection support structures, coastal flooding experience, knowledge of coastal flood risk, socio-demographic characteristics. Coordinates of each respondent's home were also collected in order to identify spatial variables that determined individuals' living environment.

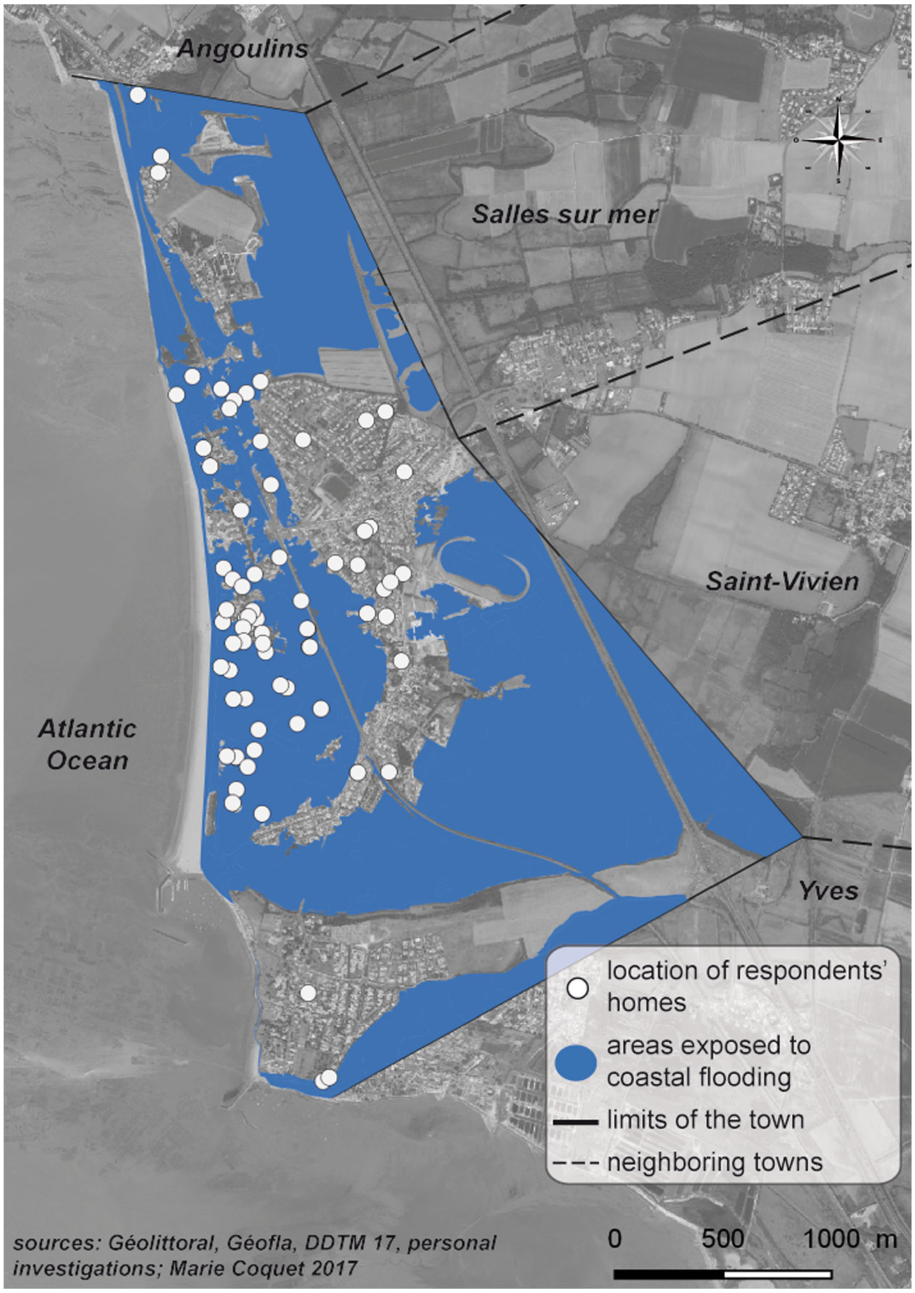

Fig. 4 Location of respondents' homes in the town of Châtelaillon-Plage

In this research paper, we focused on data from individuals' sketch maps of areas exposed to coastal flooding and on spatial variables that determined individuals' living environment.

Measures

The use of sketch maps in the analysis of individual's perceptions of natural risk

The use of GIS for assessing sketch maps has been widely generalized (Boschmann and Cubbon 2014; Cheung et al. 2016). Thus, individuals' sketch maps were geo-referenced and digitized. Two different methodologies were predominantly used in sketch map assessments and this was the case for studies which analyzed individuals' perceptions of natural risks. In the first case, individuals' sketch maps were analyzed by compilation (Brennan et al. 2016; Brilly and Polic 2005; DeChano and Butler 2001; Gaillard 2008; Gaillard et al. 2001; Leone and Lesales 2009; Pagneux et al. 2011; Ruin et al. 2007). The aim of this methodology is to capture a collective perception of hazardous areas.

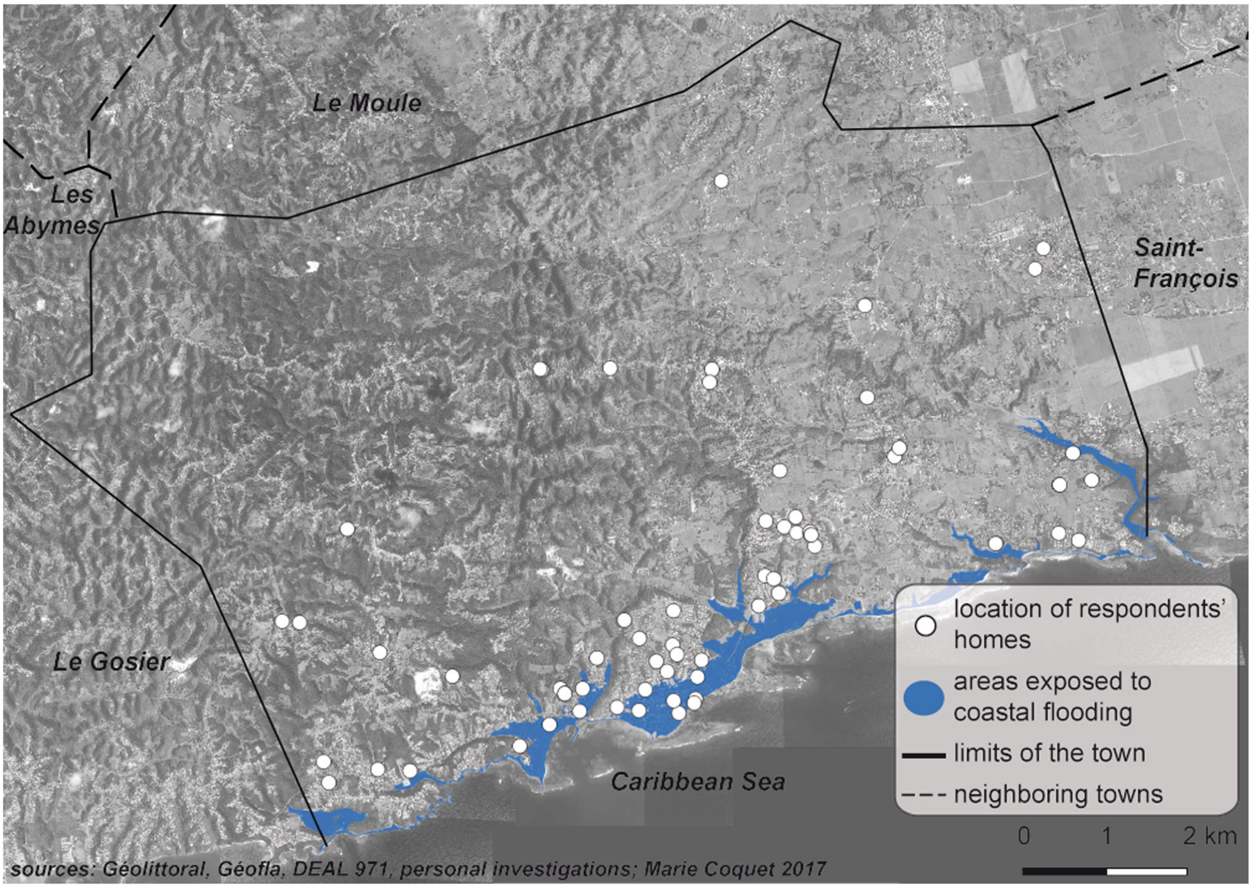

Fig. 5 Location of respondents' homes in the town of Sainte-Anne

Studies often compared an expert estimation of hazardous areas with the collective perception (Brennan et al. 2016; Pagneux et al. 2011; Ruin et al. 2007). In the second case, studies focused more on assessing sketch maps at an individual level (Cheung et al. 2016; O'Neill et al. 2015). Thus, Cheung et al.(2016) studied individuals' sketch maps of coastal flood risk in Newport Beach, California. They first determined in a first time the disparity between individuals' sketch maps and secondly the disparity between individuals' sketch maps and expert estimates of hazardous areas. In their study about individuals' perceptions of flood risk in the town of Bray, near Dublin,

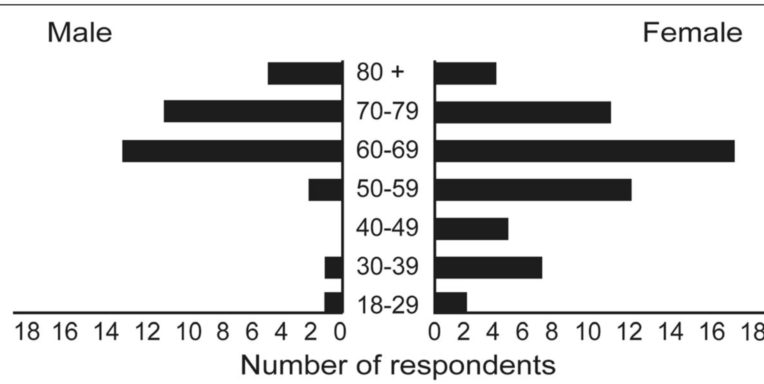

Fig. 6 Age pyramid of respondents in the town of Barneville-Carteret

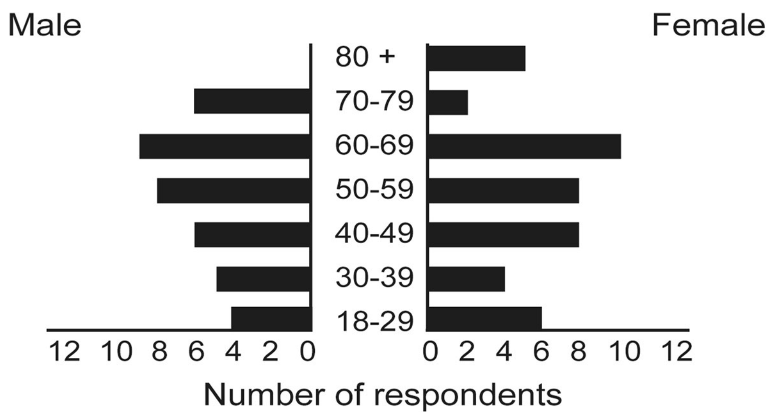

Fig. 7 Age pyramid of respondents in the town of Saintes-Maries-de-la-mer

O'Neill et al. (2015) determined the disagreement between individuals' sketch maps of flood risk with an objective estimation of flood risk.

Assessment of sketch maps

Collecting data using sketch map base For the three study sites of Barneville-Carteret, Saintes-Maries-de-la-mer and Châtelaillon-Plage, the base maps included an ortho-photography, a north arrow and a scale bar. Figure 10 presents an example of a sketch map made by a respondent in Châtelaillon-Plage. Respondents from Barneville-Carteret and Châtelaillon-Plage were asked to sketch the areas exposed to coastal flooding for all the surface areas of the towns. As explained in the introduction, because of the very large surface area of Saintes-Maries-de-la-mer we delimited the sketch mapping around the village, where a large majority of respondents lived. The Sainte-Anne respondents found it very difficult to orientate themselves using the ortho-photograph. This was due in particular to the high density of vegetation cover that screened the road network and certain housing areas. To help them overcome their difficulties, we gave them an open street map base highlighting the coastline, the town limits, the main roads, some reference locations (such as the church, the cemetery and the stadiums), the main sections of the municipality, a north arrow and a scale bar (Fig. 11). We gave each respondent a pen to sketch areas exposed to coastal flooding but they were free to use a pencil, a felt tipped pen or a highlighter.

Processing of the sketch maps We used QGIS GIS software for the processing of the sketch maps. Each sketch map is geo-referenced. The areas that respondents sketched as exposed to coastal flooding are digitized and cropped, where necessary, according to the limits of the municipality (GEOFLA IGN) and the coastline (HistoLitt SHOM IGN). We the compared individuals' sketch maps with experts' estimates of hazardous areas.

In France, the main instrument of coastal risk management is the PPRl (*Plan de Prevention des Risques littoraux* or coastal risk prevention plan). PPR (*Plan*

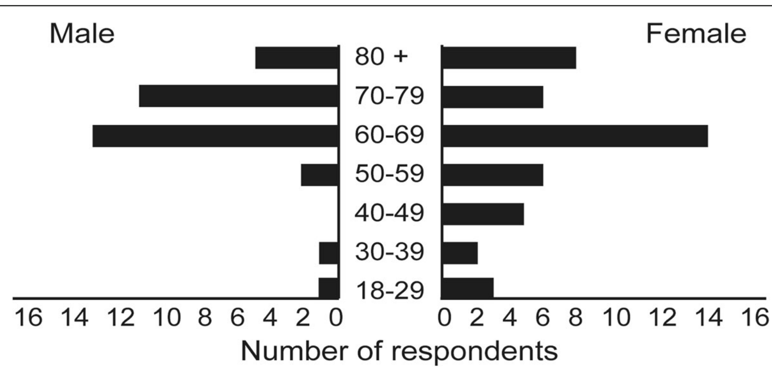

Fig. 8 Age pyramid of respondents in the town of Châtelaillon-Plage

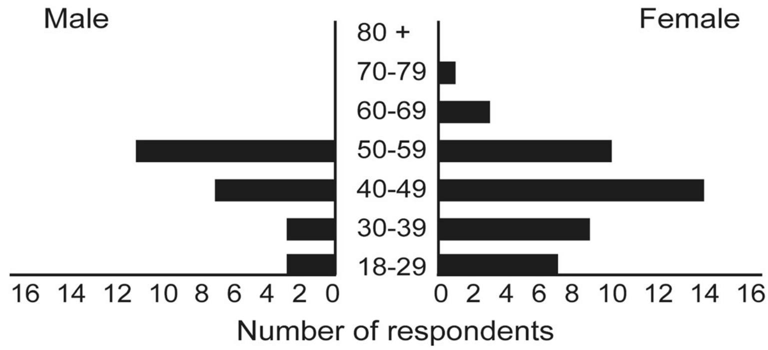

Fig. 9 Age pyramid of respondents in the town of Sainte-Anne

de Prevention des Risques equivalent to risk prevention plans) were developed in 1995 at *communes* level (the lowest level of government). They aimed to organize urbanization considering risks (Chadenas et al. 2014; Pottier et al. 2005). Following storm Xynthia which highlighted the necessity to improve coastal risk management, the French government started revisioning the PPRl. The new PPRl had to include a more precise understanding of coastal flooding hazards, the effects of protection structures and the sea live rise (Perherin et al. 2012) in order to create a more refined modeling of coastal flooding hazards. Thus, the urbanization regulatory map is the combination of a stakes map and a hazards map and determines areas within which construction is forbidden or with limited (MEDDE 2014). The hazards map determines the areas exposed to different scenarios of coastal flooding hazard: a current scenario and a scenario that includes the effect of climate change up to 2100 (MEDDE 2014). We used the current one in the present research. We disposed of the coastal flooding hazard maps of Barneville-Carteret and Châtelaillon-Plage.

The revision procedures of the PPRl for Sainte-Anne and Saintes-Maries-de-la-mer, the procedure of revision of the PPRl weren't advanced enough to access coastal flood hazard maps. However these two municipalities were identified as TRI ("*Territoires à Risques Importants d'inondation*", or high risk flood areas). The identification of TRI takes place in a larger context of the implementation of the European Directive nb 2007/60/CE (23/10/2007) relating to the assessment and the management of flood risk. A TRI is not a substitute for a PPRL but the identification process of a TRI can lead to the definition of a PPRL. A TRI is an area, for example a group of municipalities, exposed to flooding (coastal flooding included). As with the PPRl document, the TRI document combines stake maps and hazard maps including a current hazard map. Thus, we decided to use both types of coastal current flooding hazards maps because the methodology used to assess current coastal flooding hazard in the TRI was similar to that in the PPRl.

In order to compare individuals' sketch maps with experts' estimates of hazardous areas we decided to use coastal flooding hazard maps from PPRl and TRI documents. To assess the disagreement between individuals' sketch maps with experts' estimates of hazardous areas we constructed three indicators.

The over-assessment indicator represents the proportion of sketched areas which does not intersect the coastal flooding hazard mapping (in yellow on Fig. 12). Thus, the "over-assessed areas" reflect respondents' perception that some places are exposed to coastal flooding whereas they are not according to hazard mapping.

The under-assessment indicator is the proportion of coastal flood hazard mapping which do not intersect the sketched areas (in blue on Fig. 12). In contrast to the over-assessed areas, the under-assessed areas reflect the respondents' perception that some places are not exposed to coastal flooding whereas in fact they are according to hazard mapping. Consequently, a respondent may over-assess the exposure to coastal flooding in some places and under-assess it in other places.

The indicator of similarity corresponds to the Jaccard similarity coefficient (J). It is used to compare the similarity of two samples. It corresponds to the size of the intersection divided by the size of the union of the samples as:

$$J(A,B) = \frac{A \cap B}{A \cup B}.$$

Here, the samples are on the one hand the coastal flooding hazard mapping (A) and on the other the sketched areas exposed to coastal flooding (B) (Fig. 13). This indicator varies between 0 (the samples are not similar) to 1 (the samples are similar).

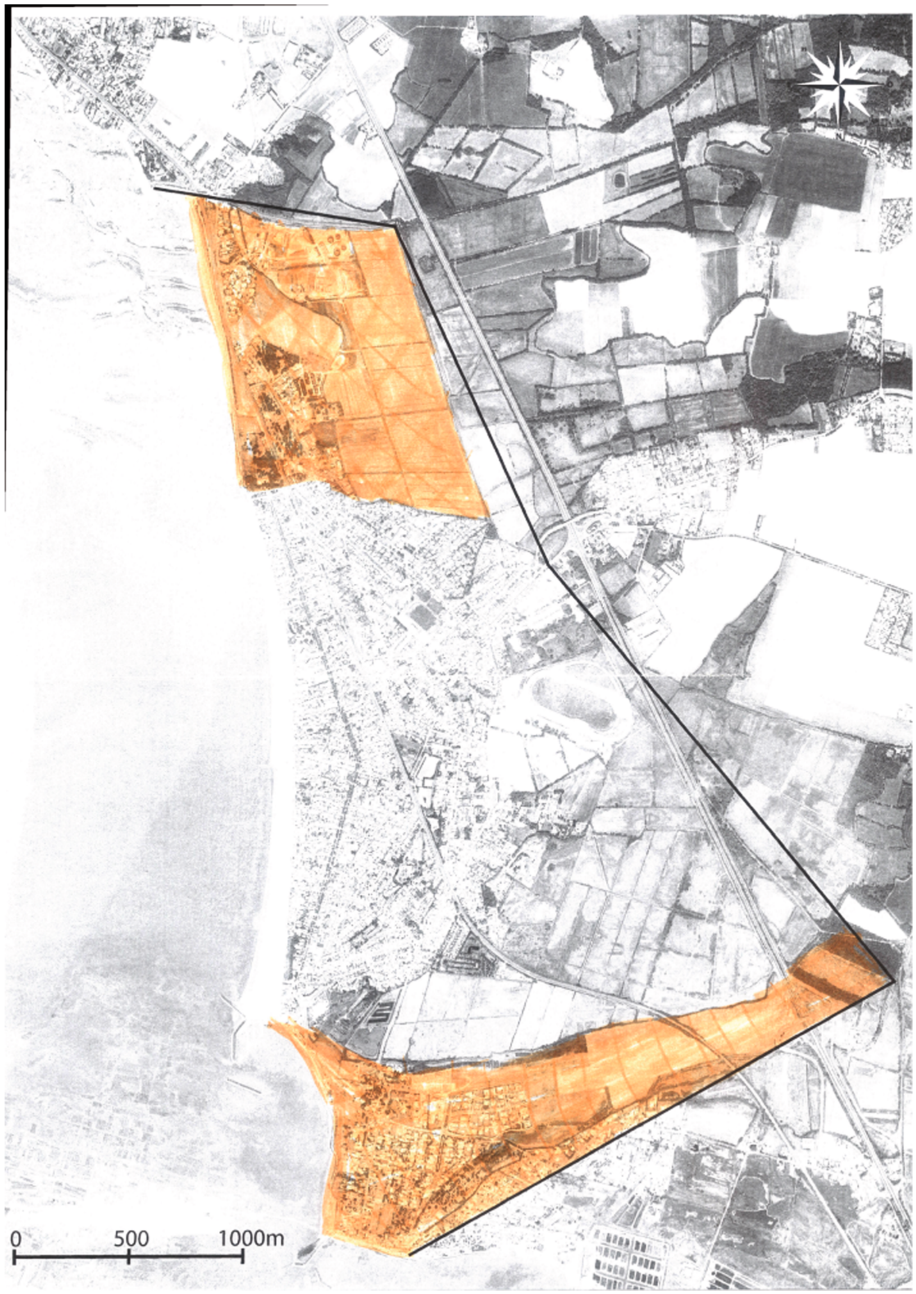

Fig. 10 Example of a sketch map made by a respondent in Châtelaillon-Plage

Characterization of individuals' living environments using spatial variables

Acquisition of the spatial variables Using QGIS GIS software and each respondent's home coordinates, we calculated four metric variables (expressed in meters): the elevation of their home above sea level, the distance from their home to the sea, the distance from their home to areas exposed to coastal flooding and the perceived distance of the home to the exposed areas exposed to coastal flooding. We used LIDAR (IGN, SHOM Litto3D) data with a spatial precision between 15 and 20 cm and an elevation precision between 20 and 50 cm to evaluate the elevation of homes above sea level. The elevation resolution was at the centimeter scale for all study sites. The spatial resolution was 0.5 m for Sainte-Anne and Barneville-Carteret, 5 m for Saintes-Maries-de-la-mer and 1 m for Châtelaillon-Plage. According to the availability of data (SHOM 2014), the distance from the homes to the sea was calculated in relation to the highest astronomical tide level for Sainte-Anne

Fig. 11 Example of a sketch map made by a respondent in Sainte-Anne

and Saintes-Maries-de-la-mer and the mean of the high spring tide level for Barneville-Carteret and Châtelaillon-Plage. The distance from the homes to the areas exposed to coastal flooding was calculated according to the current hazard maps available in the PPRL of Barneville-Carteret and Châtelaillon-Plage and available in the TRI document of Saintes-Maries-de-la-mer and Sainte-Anne. Thus, we can consider this distance as objective as possible. Lastly, the perceived distance to areas exposed to coastal flooding corresponds to the distance between one individual's home and the limit of the sketched areas. If the respondent sketched one area, we considered the distance between his/her home and the limit of the sketched area. If the respondent sketched more than one area, we considered the distance between his/her home and the limit of the closest sketched area.

Data analysis

Assessment of the disagreement between individuals' perceptions and experts' estimates of areas exposed to coastal flooding

We expected differences in respondents' indicators of sketch mapping depending on where they lived. Therefore, in order to study variations in respondent's indicators of sketch mapping between the study sites, we performed an analysis of variance (ANOVA) for each indicator where the study sites were used as between-factor subject. Then, pairwise comparisons (Bonferroni post hoc test) were conducted in order to understand where the differences occurred.

The relationship between individuals' perceptions of areas exposed to coastal flooding and the characteristics of their living environment

We aimed to analyse the relationship of the four spatial variables (the altitude of the home, the distance of the home to the sea the distance of the home to the areas exposed to coastal flooding and the perceived distance of the home to the areas exposed to coastal flooding) and individuals' perceptions of areas exposed to coastal flooding determined by sketch mapping indicators. We considered the sketch mapping indicators (over-assessment, under-assessment and similarity) as dependent variables and the four spatial variables as factors (or independent variables). We used hierarchical partitioning of R^2 to determine the proportion of variance of sketch mapping indicators explained by each spatial variable (Chevan and Sutherland 1991). This method allowed us

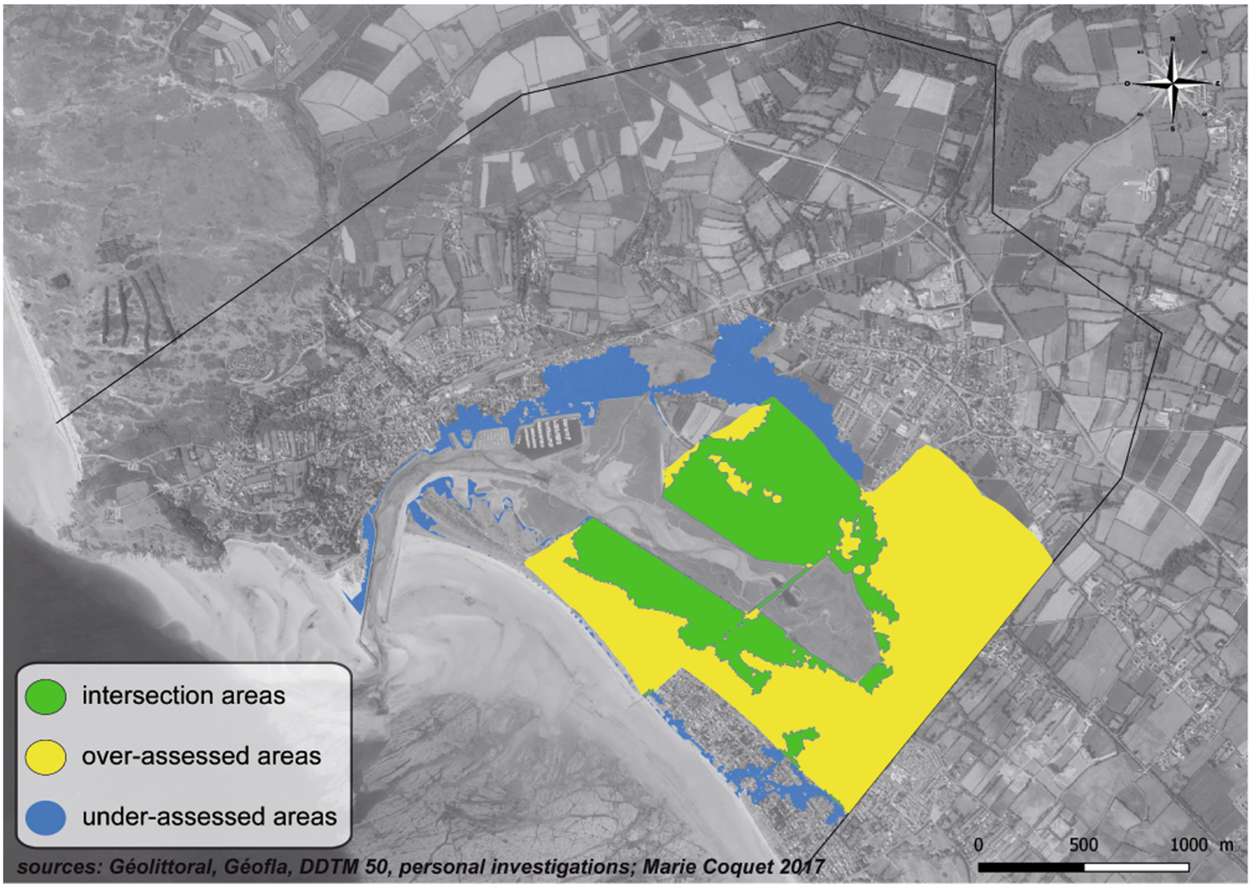

Fig. 12 Spatial processing of individuals' sketch maps by comparison with experts' estimates of hazardous areas (exemple of a respondent's sketch map in Barneville-Carteret). In green: intersection areas between individuals' sketch maps and experts' estimates of hazardous areas. In blue: experts' estimates of hazardous areas which do not intersect individuals' sketch maps. In yellow: individuals' sketch maps which do not intersect experts' estimates of hazardous areas

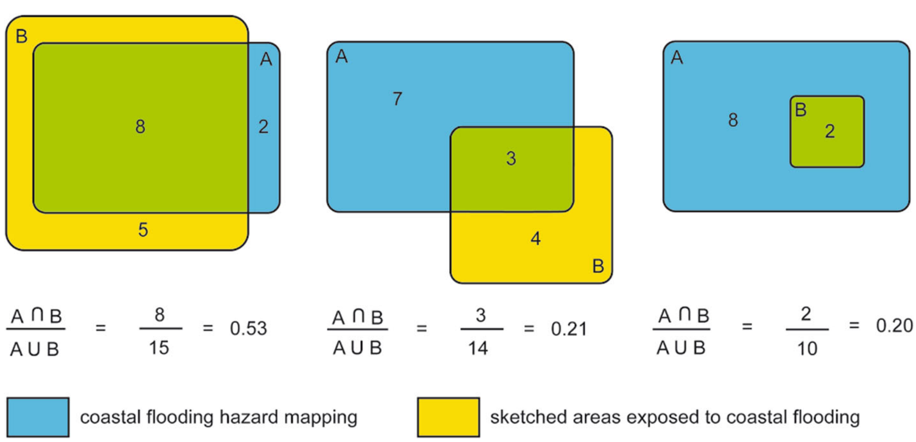

Fig. 13 Application of Jaccard similarity coefficient to sketch maps processing

to identify variables that have important independent correlation with the dependent variable, unlike variables that have a small independent effect but a high correlation with the dependent variables due to correlation with the other explanatory (or independent) variables. Secondly, we ordered spatial metrics that significantly and independently explain a proportion of variance. Significance of spatial metrics was determined by comparing the values of the independent contributions *I* with a population of *I*s from 1000 randomizations of the data matrix. Significance was accepted above 95% confidence limit.

We didn't consider the variable of distance to the sea to the areas exposed to coastal flooding for Saintes-Maries-de-la-mer because all the respondents lived in areas exposed to coastal flooding so the value was equal to 0 for each individual.

In preparation for data processing, we removed individuals which didn't sketch the areas exposed to coastal flooding because they considered that no area was exposed. Those individuals represented 9.9% of the Saintes-Maries-de-la-Mer respondents, 6.5% of the Châtelaillon-Plage respondents and 3.3% of the in Sainte-Anne respondents. No respondents from Barneville-Carteret were included. Therefore, the global sample was reduced to 303 individuals.

Results

Assessment of the disagreement between individuals' perceptions and expert estimates of areas exposed to coastal flooding

Sketch mapping indicators were built in order to assess the spatial disagreement between individuals' perceptions and experts' estimates of areas exposed to coastal flooding. Thus, we chose to assess the disagreement using indicators of over-assessment, under-assessment and similarity. Table 1 presents the descriptive statistics for the sketch mapping indicators. To confirm the differences between study sites which appeared in the descriptive statistics, we performed analysis of variance for each sketch mapping indicator and determined significant differences.

Indicator of over-assessment

The range of indicators of over-assessment was very wide (from around 0% for all study sites to above 90%, except for Sainte-Maries-de-la-mer). Respondents from Sainte-Anne and Barneville-Carteret displayed average indicators of over-assessment (Sainte-Anne: 64%, Barneville-Carteret: 49%) higher than the average of respondents of all four study sites (44%) They were more likely than the respondents from Saintes-Maries-de-la-mer (25%) and Châtelaillon-Plage (39%) to perceive areas as exposed to coastal flooding which are not identified as hazardous areas by experts' estimations (from TRI document in this case). Respondents from Saintes-Maries-de-la-mer are the least likely to over assess the spatial extent of coastal flooding areas in comparison to the experts' hazards map. We had difficulties in calculating the over-assessment indicator for each respondent from Saintes-Maries-de-la-mer. In fact, almost the whole surface area of the map is considered to be exposed to coastal flooding. The parts they are not considered to be exposed, mostly consisted of marshes and ponds, are already submersible. Consequently, areas that respondents identified as exposed to coastal flooding which are not identified in the hazards map are mostly marshes and pounds.

Table 1 Descriptive statistics for the sketch mapping for the study sites

Sketch mapping indicators	*N*	Min	Max	Mean	SD	*N*	Mean	SD
Over-assessment indicator								
Barneville-Carteret	92	0.05	99.39	48.63	23.93	303	43.90	23.60
Saintes-Maries-de-la-Mer	73	0.00	75.55	24.76	14.60			
Châtelaillon-Plage	72	0.00	93.39	38.84	17.09			
Sainte Anne	66	0.00	96.75	64.01	18.68			
Under-assessment indicator								
Barneville-Carteret	92	5.76	99.99	69.39	24.59	303	77.69	24.58
Saintes-Maries-de-la-Mer	73	2.44	100	82.94	29.01			
Châtelaillon-Plage	72	0.20	100	85.15	22.93			
Sainte Anne	66	33.88	97.41	75.32	16.06			
Similarity indicator								
Barneville-Carteret	92	0.00	0.51	0.20	0.13	303	0.15	0.14
Saintes-Maries-de-la-Mer	73	0.00	0.61	0.13	0.18			
Châtelaillon-Plage	72	0.00	0.61	0.12	0.15			
Sainte Anne	66	0.01	0.24	0.13	0.07			

The difference in respondents' indicators of over assessment according to their place of residence was significant (F (3; 299) = 51.52, $p < 0.001$). Thus, the effect of the study site factor was high ($\eta^2 = 0.341$) according to Cohen's standards (Cohen 1988). In fact, more than 34% of the variations in indicators of over-assessment were explained by the study site. Pairwise comparisons present significant ($p < 0.01$) differences in indicators of over-assessment between all groups of respondents depending on their study sites (Fig. 14a).

Indicator of under-assessment

The variability of indicators of under-assessment was very large except for Sainte-Anne. Thus, if respondents from the three other study sites displayed indicators from 0.20% to 100%, those from Sainte-Anne presented a minimum indicator of 33.9%. The average indicators of under-assessment (78%) were higher than the average indicators of over-assessment (44%) for all study sites. Thus, respondents were more likely to under-assess than over-assess the spatial extent of areas exposed to coastal flooding. Average indicators of under-assessment of respondents from Châtelaillon-Plage (85%) and from Saintes-Maries-de-la-mer (83%) were higher than the average indicator (78%). Despite the fact that the average indicators of over-assessment and under-assessment of respondents in Saintes-Maries-de-la-mer were less precise in their calculation than the other study sites, they provided information about the general trend of individuals' perception of the spatial extent of areas exposed to coastal flooding. In fact, respondents that lived in this municipality are more likely to under-assess than over-assess the exposed areas.

The difference in respondents' indicators of under assessment according to their place of residence was significant (F (3; 299) = 7.48, $p < 0.001$). This time, the effect of the study site factor was medium ($\eta^2 = 0.070$) according to Cohen's standards. So, 7% of the variations in indicators of under-assessment were explained by the study site. Pairwise comparisons (Fig. 14b) showed significant ($p < 0.01$) mean differences in indicators of under-assessment between respondents from Barneville-Carteret and Saintes-Maries-de-la-mer and also between respondents from Barneville-Carteret and Châtelaillon-Plage.

Respondents who lived in Châtelaillon-Plage and Saintes-Maries-de-la-mer had the lowest average indicators of over-assessment and the highest average indicators of under-assessment. The study sites of Châtelaillon-Plage and Saintes-Maries-de-la-mer presented the highest percentages of areas exposed to coastal flooding. In fact, these areas represented 66% of the entire surface area of Châtelaillon-Plage. As previously stated, it was not possible to have an accurate percentage of areas exposed to coastal flooding in Saintes-Maries-de-la-mer and but it represents almost the whole surface area of the study site. On the contrary, respondents from Barneville-Carteret and Sainte-Anne had the highest average indicators of over-assessment and the lowest indicators of under-assessment whereas both study sites had the lowest percentage of areas exposed to coastal flooding of

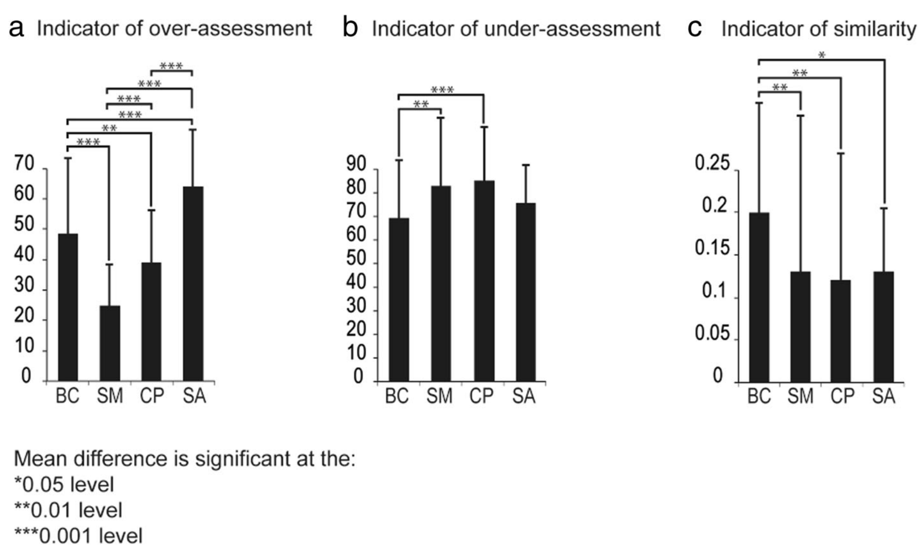

Fig. 14 Differences between means for sketch mapping indicators (**a**, **b** and **c**) between the study sites. Legend: Bar charts showing variations in the three indicators of sketch mapping (values represent mean and standard deviation) in the four study sites. Differences between means are significant at the 0.05 level*, 0.01 level** and 0.001 level***. Abbreviations: "BC" for Barneville-Carteret, "SM" for Saintes-Maries-de-la-Mer, "CP" for Châtelaillon-Plage and "SA" for Sainte-Anne

their entire surface areas (respectively 12% and 2.5%). To sum up, respondents from study sites which presented the highest rate of areas exposed to coastal flooding are more likely to under-assess the spatial extent of those areas.

Indicator of similarity

Only the respondents who lived in Barneville-Carteret displayed an average indicator of similarity (0.2) higher than the average from all the study sites (0.15). That means, on average, 20% of the areas they perceived as exposed to coastal flooding were the same as those of the hazards maps (from PPRL document). Respondents from the three other study sites had an average indicator of similarity of 0.12 and 0.13 with higher deviation for the respondents who lived in Saintes-Maries-de-la-mer (standard deviation = 0.18). We noticed a wide range of indicators of similarity among study sites except, once again, for respondents from Sainte-Anne.

The difference among respondents' indicators of similarity according to their place of residence was significant (F (3; 299) = 5.96 $p < 0.001$). The effect of the study site factor was medium ($\eta^2 = 0.056$) according to Cohen's standards. That means around 5.5% of the variations in indicators of similarity was explained by the study site. Pairwise comparisons (Fig. 14c) showed significant ($p < 0.05$) differences in means for indicators of under-assessment between respondents from Barneville-Carteret and respondents from each of the other study sites.

Characteristics of individuals' living environment

Table 2 presents the ranges, minimums, maximums, means and standard deviations for the four spatial variables which reflect the special features of each study site, as presented above. For example, in Saintes-Maries-de-la-mer, the mean elevation of respondents' homes is very low (1 m above sea level) and all respondents lived in an area exposed to coastal flooding. This is due to the ocation of the town in the Rhone delta. Standard deviations for the distances to the sea are very high because of the diversity of locations of respondents' homes. Mean distances to areas exposed to coastal flooding are very different depending on the study site. They are especially related to the percentage of the town area overlapping by the exposed coastal flood area. Thus, areas exposed to coastal flooding represent 12% of the total area of Barneville-Carteret. Respondents live on average 94 m from areas exposed to coastal flooding. These areas represent 66% of the total area of Châtelaillon-Plage, so respondents could potentially live closer to them. In fact, they live on average 30 m away. In Sainte-Anne, the exposed coastal flood areas represent only 2.5% and residents live on average 760 m from them.

Table 2 Descriptive statistics for the spatial variables using coordinates of each individual's home in the study sites

Spatial variables (meters)	*N*	Min	Max	Mean	SD	*N*	Mean	SD
Distance to the sea								
Barneville-Carteret	92	10	1037	264.8	270.7	303	677.8	1186.9
Saintes-Maries-de-la-Mer	73	25	8774	956.5	1887.8			
Châtelaillon-Plage	72	81	989	408.0	274.8			
Sainte-Anne	66	27	6700	1239.7	1297.1			
Distance to areas exposed to coastal flooding								
Barneville-Carteret	92	0	795	94.5	156.2	303	200.2	575.3
Saintes-Maries-de-la-Mer	73	0	0	0.0	0.0			
Châtelaillon-Plage	72	0	302	29.3	61.5			
Sainte-Anne	66	0	4698	755.5	1045.4			
Perceived distance to areas exposed to coastal flooding								
Barneville-Carteret	92	0	2821	245.1	418.9	303	714.2	1184.0
Saintes-Maries-de-la-Mer	73	0	11,121	980.1	1677.5			
Châtelaillon-Plage	72	0	302	571.8	667.7			
Sainte-Anne	66	0	4698	1229.2	1407.6			
Elevation								
Barneville-Carteret	92	4.6	34.6	10.8	7.0	303	10.9	17.5
Saintes-Maries-de-la-Mer	73	−0.5	3.4	1.3	0.5			
Châtelaillon-Plage	72	2.5	14.4	3.8	1.5			
Sainte-Anne	66	1.3	114.0	29.6	28.8			

Regarding the means of the perceived distances, we first noticed that for every study site the perceived distances are higher than the objective ones. In Saintes-Maries-de-la-Mer, every respondent lived in areas exposed to coastal flooding according to the hazards maps but they perceived living on average at 980 m from areas exposed to coastal flooding. Respondents in Barneville-Carteret perceived living on average at 245 m from exposed areas, that being 2.6 times more than the average objective distance. 27.2% of the respondents (25 individuals) who actually lived in exposed areas (according to experts' hazard maps) estimated that they lived in exposed areas. 9.8% of the respondents (9 individuals) who didn't actually live in exposed areas estimated that they didn't live in exposed areas. 9.8% (9 individuals) who didn't actually live in exposed areas estimated that they lived in exposed areas. In Saintes-Maries-de-la-mer 34.2% (25 individuals) who actually lived in exposed areas estimated that they lived in exposed areas. 65.8% (48 individuals) who actually lived in exposed areas estimated that they didn't live in exposed areas. In Châtelaillon-Plage respondents perceived to live on average 19.5 times more than the average objective distances. 11.1% (8 individuals) who actually lived in exposed areas estimated that they lived in exposed areas. 54.2% (39 individuals) who actually lived in exposed areas estimated that they didn't live in exposed areas. 2.7% (2 individuals) who didn't actually live in exposed areas estimated that they lived in exposed areas. At least, respondents from Sainte-Anne who perceived to live on average 1.6 times more than the average objective distances. 7.6% (5 individuals) who actually lived in exposed areas estimated that they lived in exposed areas. 1.5% (1 individual) who actually lived in an exposed area estimated that he or she didn't live in an exposed area. 12.1% (8 individuals) who didn't actually live in exposed areas estimated that they lived in exposed areas.

The relationship between individuals' perceptions of areas exposed to coastal flooding and the characteristics of their living environment

We aimed to determine the relationship between individuals' living environments and the way they perceived the spatial extent of coastal flooding. The results presented here show the hierarchical partitioning of variance using sketch mapping indicators (over-assessment, under-assessment and similarity) as dependent variables and the four spatial variables as factors (or independent variables) for each study site.

Barneville-Carteret

In Barneville-Carteret (Fig. 15), spatial variables significantly explained ($R^2 = 0.16$; $p < 0.05$) the over-assessment indicator. This indicator was significantly ($p < 0.5$) and only explained by the distance of the home to the sea (positive relation; 69.9% of the total variance explained by all the spatial variables). Spatial variables explained significantly ($R^2 = 0.21$; $p < 0.05$) the over-assessment indicator. It was significantly ($p < 0.5$) and best explained by the perceived distance to areas exposed to coastal flooding (positive relation; 51.10%) and the objective distance of the home to areas exposed to coastal flooding (negative relation; 30.4%). At last, spatial variables explained significantly ($R^2 = 0.22$; $p < 0.05$) the indicator of similarity. This indicator was significantly ($p < 0.5$) and best explained by the perceived distance to areas exposed to coastal flooding (negative relation; 43.8%) and the objective distance of the home to areas exposed to coastal flooding (positive relation; 38.2%).

To sum up, respondents from Barneville-Carteret who live far from the sea are more likely to over-assess the spatial extent of coastal flooding in areas which are not exposed according to expert assessment. Respondents who live close to the areas exposed to coastal flooding are more likely to under-assess the spatial extent of coastal flooding in areas which are exposed according to expert assessment. Respondents who perceived themselves as living far from the areas exposed to coastal flooding are more likely to under-assess spatial extent of coastal flooding in areas which are exposed according to expert assessment. Estimations of respondents who live far from areas exposed to coastal flooding tend to be similar to expert assessments. Estimations of respondents who perceived themselves as living close to areas exposed to coastal flooding tend to be similar to expert assessments.

Saintes-maries-de-la-mer

Concerning Saintes-Maries-de-la-mer (Fig.15), spatial variables did not significantly explain the over-assessment indicator. They significantly explained ($R^2 = 0.06$; $p < 0.05$) the under-assessment indicator. This indicator was significantly ($p < 0.5$) and only explained by the perceived distance to areas exposed to coastal flooding (positive relation; 83.30%). Spatial variables significantly explained ($R^2 = 0.07$; $p < 0.05$) the indicator of similarity. It was significantly ($p < 0.5$) and only explained by the perceived distance to areas exposed to coastal flooding (negative relation; 81.4%).

To summarize, in Saintes Maries de la mer, respondents who perceived themselves as living far from the areas exposed to coastal flooding are more likely to under-assess the spatial extent of coastal flooding in areas which are exposed according to expert assessment. Estimations of coastal flood extent by respondents who perceived themselves as living close to areas exposed to coastal flooding tend to be similar to expert assessments.

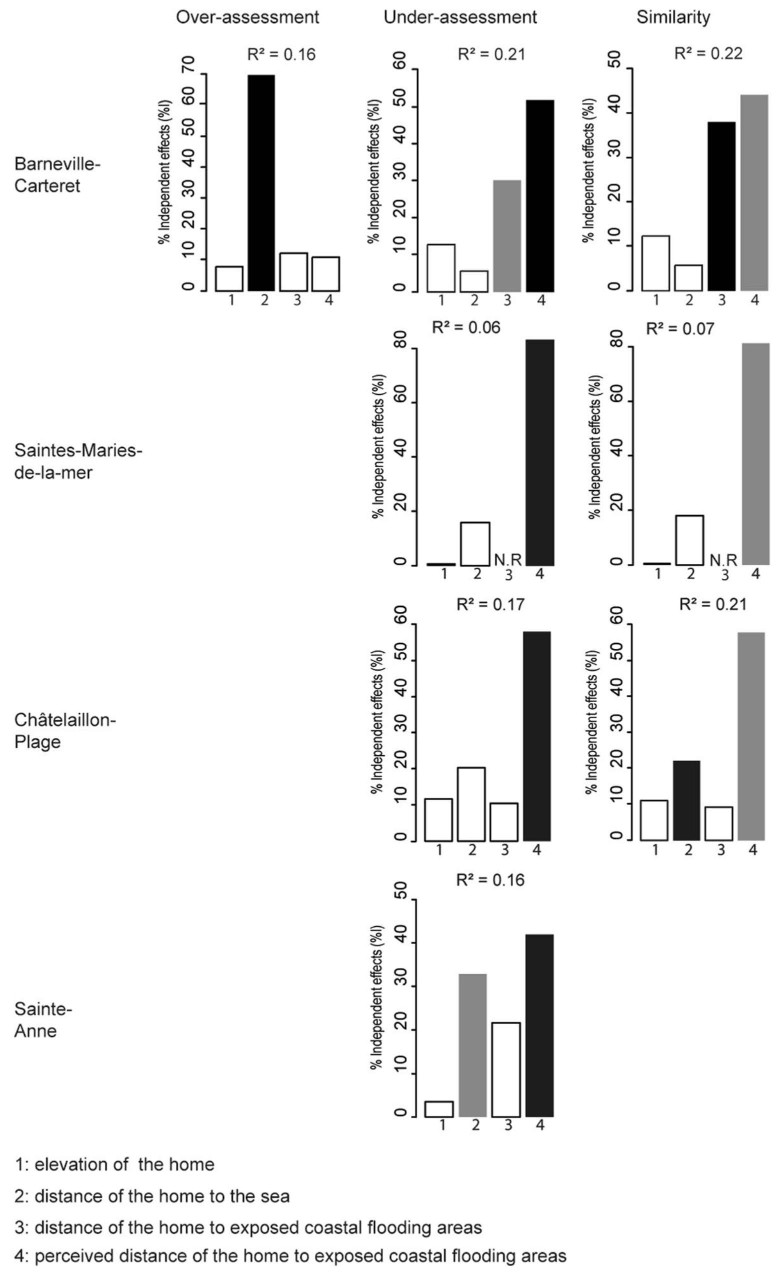

Fig. 15 Relationships between the spatial variables and the sketch mapping indicators (over-assessment, under-assessment and similarity). Legend: The bar charts represent the percentage of explained variance in each sketch mapping indicator for each of the four factors independently (elevation of the home, 2: distance of the home to the sea, 3: distance of the home to exposed coastal flooding areas, 4: perceived distance of the home exposed coastal flooding areas) as determined by the hierarchical partitioning. The R^2 are coefficients of determination of multiple linear regressions with each sketch mapping indicator as a dependent variable and the four spatial variables as factors. The black bars represent a significant correlation with positive relationship and the gray bars a significant correlation with negative relationship. The white bars illustrate a non-significant correlation and "N.R" (non-relevant) meaning that we didn't use a factor

Châtelaillon-Plage

Regarding Châtelaillon-Plage (Fig. 15), spatial variables did not significantly explain the over-assessment indicator. They significantly explained ($R^2 = 0.17$; $p < 0.05$) the under-assessment indicator. It was significantly ($p < 0.5$) and only explained by the perceived distance to areas exposed to coastal flooding (positive relation; 57.90%). Spatial variables significantly explained ($R^2 = 0.21$; $p < 0.05$) the indicator of similarity. This indicator was significantly ($p < 0.5$) and best explained by the perceived distance to areas exposed to coastal flooding (positive relation; 81.4%) and the distance of the home to the sea (positive relation; 22.1%).

To recap, in Châtelaillon-Plage, respondents who perceived themselves as living far from the areas exposed to coastal flooding are more likely to under-assess spatial the extent of coastal flooding in areas which are exposed according to expert assessment. Estimations of respondents who live far from the sea are more likely to be similar to expert assessments. Estimations of respondents who perceived themselves as living close to areas exposed to coastal flooding tend to be similar to expert assessments.

Sainte-Anne

Spatial variables did not significantly explain the over-assessment indicator (Fig. 15). They significantly explained ($R^2 = 0.16$; $p < 0.05$) the under-assessment indicator. This indicator was significantly ($p < 0.5$) and best explained by the perceived distance to areas exposed to coastal flooding (positive relation; 41.9%) and the distance of home to areas exposed to coastal flooding (negative relation; 32.9%). Spatial variables did not significantly explain the indicator of similarity.

To sum up, respondents from Sainte-Anne who live close to the sea are more likely to under-assess the spatial extent of coastal flooding in areas which are not exposed according to expert assessment. Respondents who perceived themselves as living far from the areas exposed to coastal flooding are more likely to under-assess spatial extent of coastal flooding in areas which are exposed according to expert assessment.

Discussion

Disagreement between individuals' perceptions and expert estimates of areas exposed to coastal flooding

We aimed to assess the disagreement between expert assessments of the extent of areas exposed to coastal flooding with individuals 'sketch maps of areas exposed to coastal flooding. We determined that, on average, respondents across the four study sites are more likely to under-assess (78% on average) than over assess (44% on average) the spatial extent of areas exposed to coastal flooding according to expert assessments. This trend has been confirmed in several studies which compared individuals' assessment and expert assessment of the spatial extent of risk. In their study about perception of ice-jam floods in Iceland, Pagneux et al. (2011) compared individuals' sketch maps of boundaries of the flood area with an experts' flood hazard map. They determined that a majority of respondents ignored areas which were actually flooded in the past. In this case individuals were more likely to under-estimate the spatial extent of a flood area. Ruin et al. (2007) analyzed motorists' perception of flood risk on roads in Southern France. Using a road map, they asked respondents to localize the areas of the road network they estimated as dangerous or safe in terms of flood hazard. Respondents' sketch maps were compared with a map of road sections reported as being regularly flooded by the department of transportation. The authors concluded that motorists tend to under-estimate the risk on secondary roads and over-estimate the risk in other areas. Brennan et al. (2016) compared the lay perception of flood risk with expert assessment of flood risk by analyzing a residential population's perception of flood risk in the city of Bray (near Dublin). In the survey, respondents were asked to delineate areas they estimated to be exposed by severe flood event. Density maps were created by aggregating the sketch maps of the entire sample of respondents or subgroups of respondents. These density maps were then compared with expert assessment of the spatial extent of a past flood using a spatial statistical tool (Fuzzy Kappa comparison). Our results are comparable with the authors' findings regarding on the entire sample of respondents. Thus, they determined that 43% of the expert assessment of flood spatial extent was similar to the average surface area of individuals' estimates. So, we could deduce that individuals under-assessed on average 57% of the expert assessment of the flood spatial extent. Brennan et al. (2016) assessed that 35% of the average surface area of individuals 'estimates did not cover the expert assessment of the flood spatial extent. This percentage is almost similar to the over-assessment indicator that we used. Cheung et al. (2016) conducted a study on individuals' sketch maps of flood risk in Newport Beach, California. They aimed to assess the agreement between individuals' sketch maps and two modeled distributions of areas exposed to flood risk. They determined that, on average, between 40% and 42% (depending on the modeled distribution) of all areas estimated to be hazardous by the models were also identified as hazardous by individuals. So, in order to make a comparison with our findings, we could determine that, on average, between 60% and 58% of areas estimated to be hazardous by the models were under-estimated by the respondents. Cheung et al. (2016) also assessed that, on average, between 31% and 39% of all areas estimated to be hazardous by individuals sketches were also identified as hazardous by the models. Thus, on average 69% and 61% of individuals' assessment of the spatial extent of flood risk is over-estimated. Contrary to our results, the authors found that respondents are more likely to overestimate than under estimate. In order to compare individual's flood risk perception with an objective measure of flood risk in the city of Bray (near Dublin), O'Neill et al. (2015) used area based indicators some of which are comparable to the indicators we used in this present study. The authors showed similar findings to ours. They determined that respondents' sketch maps identified on average 43% of the objective spatial extent of a past flood. Thus, respondents may under-estimated on average 57% of the objective spatial extent. O'Neill et al. (2015) also assessed that, on average, 65% of the respondents' sketch maps overlapped with the objective flood extent. Thus, we can infer that on average, 35% of the respondents 'sketch maps are over-estimated. Furthermore, we assessed an average indicator of similarity of 0.15 between expert assessments of the extent of areas exposed to coastal flooding with individuals 'sketch maps of areas exposed to coastal flooding. O'Neill et al. (2015) used a LSI indicator that was similar as our similarity indicator. They determined that, on average, the similarity indicator between respondents' sketch maps and the objective spatial extent of flooding was 0.29.

The relationship between individuals' perceptions of areas exposed to coastal flooding and the characteristics of their living environment

We confirmed our hypothesis that there are relationships between individuals' living environment and the way they perceive the spatial extent of coastal flooding. We performed multiple regression analysis using hierarchical partitioning to assess the relationship between each sketch mapping indicator and the spatial variables of individuals' living environments for each study site. To our knowledge, there has been no study about the relationship between individuals' sketch maps of coastal flood risk areas and the characteristics of their living environment. Nevertheless it was possible to compare our results with studies which determined relationships between risk perception and spatial variables.

The elevation of the home

In this present research, we found no significant relationship between the elevation of the home and the indicators of sketch mapping. Some studies determined a relation between the elevation of individuals' homes and their perceptions of risk. Thus, in their study about flood risk perceptions in the Netherlands, Botzen et al. (2009) determined a negative relationship between the elevation of the home and individuals' risk perception. O'Neill et al. (2016) confirmed this trend in their study about flood risk perceptions near Dublin by determining that respondents who live further from the sea are likely to have a lower risk perception.

Objective distances of the home to hazard sources

We found significant positive relationship between the distance of the home to the sea and the indicators of over-assessment and similarity and negative relationship between this spatial metric and under-assessment indicator among study sites. We also determined significant negative relationship between the distance of the home to exposed coastal flooding areas and under-assessment indicator and significant positive relationship between this spatial metric and the indicator of similarity. The analysis of the relationship between the proximity to hazard source and the perception have been applied to several natural hazards such as hurricanes (Peacock et al. 2005; Trumbo et al. 2011), volcanoes (Haynes et al. 2007; Perry et al. 1982), floods and coastal floods. Thus, Botzen et al. (2009) showed that "the further the individual is situated from a river, the lower is the perceived flood probability". Miceli et al. (2008) investigated disaster preparedness and flood risk perception in an alpine valley in the north of Italy. They determined that disaster preparedness was positively associated with the distance of respondents' homes to hazard sources. In their study about the perception of inhabitants and tourists of flood risk on Belgian coast, Kellens et al. (2011) determined that respondents who lived in highly exposed areas displayed higher levels of perceived risk than respondents who lived in low exposure areas. Arias et al. (2017) analyzed the relationship between risk perception of tsunami and the proximity of respondents' homes in a coastal city of Chile. The authors determined that respondents who lived in a tsunami flood zone had a significantly higher risk perception compared to respondents who lived in the safe zone.

The main difference between the results of these studies and our results is that we determined that individuals who lived closer to hazard sources are more likely to under-assess the spatial extent of coastal flooding and that individuals who lived further away from hazard sources are more likely to have a similar perception to expert estimates. To explain these differences, we argued that objective distances are less important factors in assessing respondents' sketch maps of the spatial extent of coastal flooding than the individuals' perceived distances. In fact, as we saw in the results, perceived distances better explain sketch mapping indicators than objective distances.

Perceived distance to areas exposed to coastal flooding

In fact, we determined a significant positive relation between perceived distance to areas exposed to coastal flooding and the under-assessment indicator across the study sites. We also show significant negative relationship between perceived distance and the indicator of similarity. When a significant relationship between the perceived distance to areas exposed to coastal flooding and sketch mapping indicators was found, sketch mapping indicators were best explained by the perceived distance. Our results are supported by the study of O'Neill et al. (2016). To our knowledge, their study was the first to show the negative relationship between perceived distance to hazard zone and flood risk perception. Thus, as the perceived distance to hazard zone increased, flood risk perception decreased. In our study, we determined that the perceived distance to areas exposed to coastal flooding is an important factor in assessing respondents' sketch maps of the spatial extent of coastal flooding. In fact, as the perceived distance to areas exposed to coastal flooding increased, respondents' under-assessment of the spatial extent of coastal flooding increased. Moreover, as the perceived distance to areas exposed to coastal flooding increased, the similarity between individuals' perceptions of coastal flooding extent and expert estimations decreased.

Conclusion

In conclusion, we demonstrated the interest of using sketch maps in quantifying individuals' perceptions of coastal flooding by analyzing the disagreement between individuals' perceptions of the spatial extent of coastal flooding with expert estimations such as hazard maps at a local scale. We determined a general indicator of similarity between the two spatial extents of 15% (from 12% to 20% depending on the study site) across the four study sites. Moreover, we found respondents were more likely to under-assess the exposure of areas that are actually exposed according to expert hazard maps (78% on average) than to over-assess the exposure of areas that are not actually exposed according to expert hazard maps (44% on average).

Secondly, we confirmed the hypothesis of relations between individuals' perceptions of the spatial extent of coastal flooding with their living environment determined by spatial metrics. The main result was the determination of the perceived distance to areas exposed to coastal flooding as an important factor in assessing respondents' sketch maps of the spatial extent of coastal flooding across the four study sites. In fact, the perceived distance to areas exposed to coastal flooding more explained the indicators of under-assessment and similarity than the objective distances. Thus, individuals who perceived themselves as living far from exposed areas are more likely to under-assess the spatial extent of coastal flooding. On the contrary, individuals who perceived themselves as living close to exposed areas are more likely to have a perception of the spatial extent of coastal flooding similar to expert estimates.

These results contribute to the analysis of individuals 'local knowledge about the spatial extent of coastal flooding in four different communities. Thus local preventive actions could take into account the individuals' tendency to under-estimate the areas exposed to coastal flooding. Individual perception of the spatial extent of coastal flooding appeared to be more influenced by the perceived distance of the home to exposed areas than the objective distance. It is a result that raises the question about the individuals' understanding of hazard maps and regulatory maps. This may necessitate the improvement of the appropriation of these documents by the inhabitants by involving them more closely in the application and decision process that directly concerns.

Acknowledgements
We thank Maygrett Maher for proofreading this paper.

Funding
This work was supported by grants from the Fondation de France.

Availability of data and materials
The dataset supporting the conclusions of this article is included within the article.

Authors' contributions
MC: survey's conception, survey in the field, statistical treatment, survey's analysis, manuscript's redaction and corrections. DM: survey's conception, survey's analysis, manuscript's corrections. GF-B: survey's conception, survey's analysis, manuscript's corrections. All authors read and approved the final manuscript.

Author's information
The present study was conducted in the framework of the project SUBMARINE led by Pr. Mercier Denis and involving Pr. Fleury-Bahi Ghozlane and Coquet Marie, Ph.D. student. The project is supported by grants from the Fondation de France.

Competing interests
The authors declare that they have no competing interests.

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Received: 9 May 2018 Accepted: 17 September 2018
Published online: 11 October 2018

References

Arias, J.P., N.C. Bronfman, P.C. Cisternas, and P.B. Repetto. 2017. Hazard proximity and risk perception of tsunamis in coastal cities: Are people able to identify their risk? *PLoS One* 12: e0186455.

Blake, E.S., E.N. Rappaport, J.D. Jarrell, et al. 2007. *The deadliest, costliest, and most intense United States tropical cyclones from 1851 to 2006 (and other frequently requested hurricane facts)*. Miami: NOAA/National Weather Service, National Centers for Environmental Prediction, National Hurricane Center.

Boschmann, E.E., and E. Cubbon. 2014. Sketch maps and qualitative GIS: Using cartographies of individual spatial narratives in geographic research. *The Professional Geographer* 66: 236–248.

Botzen, W.J.W., J.C.J.H. Aerts, and J.C.J.M. van den Bergh. 2009. Dependence of flood risk perceptions on socioeconomic and objective risk factors: Individual perceptions of climate change. *Water Resources Research* 45. https://doi.org/10.1029/2009WR007743.

Boyer-Villemaire, U., P. Bernatchez, J. Benavente, and J.A.G. Cooper. 2014. Quantifying community's functional awareness of coastal changes and hazards from citizen perception analysis in Canada, UK and Spain. *Ocean and Coastal Management* 93: 106–120. https://doi.org/10.1016/j.ocecoaman.2014.03.016.
Breilh, J.-F., X. Bertin, É. Chaumillon, et al. 2014. How frequent is storm-induced flooding in the central part of the Bay of Biscay? *Global and Planetary Change* 122: 161–175. https://doi.org/10.1016/j.gloplacha.2014.08.013.
Breilh, J.F., E. Chaumillon, X. Bertin, and M. Gravelle. 2013. Assessment of static flood modeling techniques: Application to contrasting marshes flooded during Xynthia (western France). *Natural Hazards and Earth System Sciences* 13: 1595–1612. https://doi.org/10.5194/nhess-13-1595-2013.
Brennan, M., E. O'Neill, F. Brereton, et al. 2016. Exploring the spatial dimension of community-level flood risk perception: A cognitive mapping approach. *Environmental hazards* 15: 279–310. https://doi.org/10.1080/17477891.2016.1202807.
Brilly, M., and M. Polic. 2005. Public perception of flood risks, flood forecasting and mitigation. *Natural Hazards and Earth System Sciences* 5: 345–355.
Brown, S., and R.J. Nicholls. 2015. Subsidence and human influences in mega deltas: The case of the Ganges–Brahmaputra–Meghna. *Science of the Total Environment* 527–528: 362–374. https://doi.org/10.1016/j.scitotenv.2015.04.124.
Campbell, E., J.R. Henly, D.S. Elliott, and K. Irwin. 2009. Subjective constructions of neighborhood boundaries: Lessons from a qualitative study of four neighborhoods. *Journal of Urban Affairs* 31: 461–490. https://doi.org/10.1111/j.1467-9906.2009.00450.x.
Chadenas, C., A. Creach, and D. Mercier. 2014. The impact of storm Xynthia in 2010 on coastal flood prevention policy in France. *Journal of Coastal Conservation* 18: 529–538. https://doi.org/10.1007/s11852-013-0299-3.
Chaumillon, E., X. Bertin, A.B. Fortunato, et al. 2017. Storm-induced marine flooding: Lessons from a multidisciplinary approach. *Earth Science Reviews* 165: 151–184. https://doi.org/10.1016/j.earscirev.2016.12.005.
Cheung, W., D. Houston, J.E. Schubert, et al. 2016. Integrating resident digital sketch maps with expert knowledge to assess spatial knowledge of flood risk: A case study of participatory mapping in Newport Beach, California. *Applied Geography* 74: 56–64. https://doi.org/10.1016/j.apgeog.2016.07.006.
Chevan, A., and M. Sutherland. 1991. Hierarchical partitioning. *The American Statistician* 45: 90. https://doi.org/10.2307/2684366.
Chevillot-Miot E (2017) La résilience des territoires littoraux face au risque de submersion marine. Application sur les territoires de la Charente-Maritime et de la Somme. France, Université de Nantes. https://tel.archives-ouvertes.fr/tel-01659505/document.
Chionne D (2018) Contributions géographiques à la définition d'une culture du risque en milieu littoral : le cas des résidents de l'île d'Oléron (Charente-Maritime, France). Sorbonne, Université Paris 1 Panthéon Sorbonne.
Church, J.A., and N.J. White. 2006. A 20th century acceleration in global sea-level rise: an acceleration in global sea level rise. *Geophysical Research Letters* 33 (1). https://doi.org/10.1029/2005GL024826.
Cohen, J. 1988. *Statistical power analysis for the behavioral sciences*, 2. Hilsdale: NJ Lawrence Earlbaum Associates.
Combest-Friedman, C., P. Christie, and E. Miles. 2012. Household perceptions of coastal hazards and climate change in the Central Philippines. *Journal of Environmental Management* 112: 137–148. https://doi.org/10.1016/j.jenvman.2012.06.018.
Costas, S., O. Ferreira, and G. Martinez. 2015. Why do we decide to live with risk at the coast? *Ocean and Coastal Management* 118: 1–11. https://doi.org/10.1016/j.ocecoaman.2015.05.015.
Coulton, C.J., M.Z. Jennings, and T. Chan. 2013. How big is my neighborhood? Individual and contextual effects on perceptions of neighborhood scale. *American Journal of Community Psychology* 51: 140–150. https://doi.org/10.1007/s10464-012-9550-6.
Creach, A., S. Pardo, P. Guillotreau, and D. Mercier. 2015. The use of a micro-scale index to identify potential death risk areas due to coastal flood surges: Lessons from storm Xynthia on the French Atlantic coast. *Natural Hazards* 77: 1679–1710. https://doi.org/10.1007/s11069-015-1669-y.
Curtis, J.W. 2012. Integrating sketch maps with GIS to explore fear of crime in the urban environment: A review of the past and prospects for the future. *Cartography and Geographic Information Science* 39: 175–186.
Curtis, J.W., E. Shiau, B. Lowery, et al. 2014. The prospects and problems of integrating sketch maps with geographic information systems to understand environmental perception: A case study of mapping youth fear in Los Angeles gang neighborhoods. *Environment and Planning B: Planning and Design* 41: 251–271.
DDTM 13. 2017. Plan de prévention des risques naturels prévisibles (P.P.R.) inondation sur la commune de Saintes-Maries-de-la-Mer. In *Direction Départementale des Territoires de le la Mer des Bouches du Rhône*.
DDTM 50. 2015. Plan de prévention des risques littoraux de Barneville-Carteret, Saint-Georges-de-la-Rivière, Saint-Jean-de-la-Rivière, Portbail, Saint-Lô-d'Ourville. In *Direction Départementale des Territoires de le la Mer de la Manche*.
DeChano, L.M., and D.R. Butler. 2001. Analysis of public perception of debris flow hazard. *Disaster Prevention and Management: An International Journal* 10: 261–269.
Downs, R. M., Stea, D. (1973) Image and environment: Cognitive mapping and spatial behavior. New Brunswick, Aldine Transaction.
Gaillard, J.-C. 2008. Alternative paradigms of volcanic risk perception: The case of Mt. Pinatubo in the Philippines. *Journal of Volcanology and Geothermal Research* 172: 315–328. https://doi.org/10.1016/j.jvolgeores.2007.12.036.
Gaillard, J.-C., R. D'Ercole, and F. Leone. 2001. Cartography of population vulnerability to volcanic hazards and lahars of mount Pinatubo (Philippines): A case study in Pasig-Potrero River basin (province of Pampanga) / Cartographie de la vulnérabilité des populations face aux phénomènes volcaniques et aux lahars du Mont Pinatubo (Philippines) : Cas du bassin de la rivière Pasig-Potrero (province de Pampanga). *Géomorphologie: Relief, Processus, Environnement* 7: 209–221. https://doi.org/10.3406/morfo.2001.1103.
Goeldner-Gianella, L., D. Grancher, Ø. Robertsen, et al. 2017. Perception of the risk of tsunami in a context of high-level risk assessment and management: The case of the fjord Lyngen in Norway. *Geoenvironmental Disasters* 4. https://doi.org/10.1186/s40677-017-0068-y.
Golledge, R.G. 2008. Behavioral geography and the theoretical/quantitative revolution. *Geographical Analysis* 40: 239–257.
Gould, P., and R. White. 1973. *Mental maps*. Harmondsworth: Penguin Books.
Gueben-Venière, S. 2011. En quoi les cartes mentales, appliquées à l'environnement littoral, aident-elles au recueil et à l'analyse des représentations spatiales ? *EchoGéo*. https://doi.org/10.4000/echogeo.12573.
Haynes, K., J. Barclay, and N. Pidgeon. 2007. Volcanic hazard communication using maps: An evaluation of their effectiveness. *Bulletin of Volcanology* 70: 123–138. https://doi.org/10.1007/s00445-007-0124-7.
Heitz, C., and M.N. Shimabuku. 2017. The role of individuals' risk representations in risk management - case-study on lahars in Arequipa (Peru). *Geoenvironmental Disasters* 4. https://doi.org/10.1186/s40677-017-0093-x.
Horan, M. 1999. What students see: Sketch maps as tools for assessing knowledge of libraries. *Journal of Academic of Librarianship* 25: 187–201.
Hossain, N. 2018. The 1970 Bhola cyclone, nationalist politics, and the subsistence crisis contract in Bangladesh. *Disasters* 42: 187–203.
INSEE 2014, Institut national de la statistique et des études économiques. In: INSEE. https://www.insee.fr/fr/accueil
IPCC, ed. 2014. *Climate change 2014: Mitigation of climate change ; working group III contribution to the fifth assessment report of the intergovernmental panel on climate change*. New York, NY: Cambridge Univ Press.
Kellens, W., R. Zaalberg, T. Neutens, et al. 2011. An analysis of the public perception of flood risk on the Belgian coast. *Risk Analysis* 31: 1055–1068. https://doi.org/10.1111/j.1539-6924.2010.01571.x.
Koerth, J., N. Jones, A.T. Vafeidis, et al. 2013. Household adaptation and intention to adapt to coastal flooding in the Axios – Loudias – Aliakmonas National Park, Greece. *Ocean and Coastal Management* 82: 43–50. https://doi.org/10.1016/j.ocecoaman.2013.05.008.
Kolen B, Slomp R, Balen WV, Terpstra, T., Bottema, M., & Nieuwenhuis, S. (2010) Learning from French experiences with storm Xynthia; damages after a flood. ISBN 978-90-77051-77-1.
Krien, Y., B. Dudon, J. Roger, and N. Zahibo. 2015. Probabilistic hurricane-induced storm surge hazard assessment in Guadeloupe, Lesser Antilles. *Natural Hazards and Earth System Sciences* 15: 1711–1720. https://doi.org/10.5194/nhess-15-1711-2015.
Leone, F., and T. Lesales. 2009. The interest of cartography for a better perception and management of volcanic risk: From scientific to social representations.

Journal of Volcanology and Geothermal Research 186: 186–194. https://doi.org/10.1016/j.jvolgeores.2008.12.020.
Lieske, D.J., T. Wade, and L.A. Roness. 2014. Climate change awareness and strategies for communicating the risk of coastal flooding: A Canadian maritime case example. *Estuarine, Coastal and Shelf Science* 140: 83–94. https://doi.org/10.1016/j.ecss.2013.04.017.
Lumbroso, D., K. Stone, and F. Vinet. 2011. An assessment of flood emergency plans in England and Wales, France and the Netherlands. *Natural Hazards* 58: 341–363. https://doi.org/10.1007/s11069-010-9671-x.
Lutz, W., and K. Samir. 2010. Dimensions of global population projections: What do we know about future population trends and structures? *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 365: 2779–2791. https://doi.org/10.1098/rstb.2010.0133.
Lynch K (1960) The image of the city (Vol. 11). MIT press.
Matei, S., and S. Ball-Rokeach. 2005. Watts, the 1965 Los Angeles riots, and the communicative construction of the fear epicenter of Los Angeles a previous version of this paper was presented at the American sociological annual conference, Chicago, 2001. *Communication Monographs* 72: 301–323. https://doi.org/10.1080/03637750500206557.
Matei, S., S.J. Ball-Rokeach, and J.L. Qiu. 2001. Fear and misperception of Los Angeles urban space: A spatial-statistical study of communication-shaped mental maps. *Communication Research* 28: 429–463.
McGranahan, G., D. Balk, and B. Anderson. 2007. The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment and Urbanization* 19: 17–37. https://doi.org/10.1177/0956247807076960.
MEDDE (2014) Guide méthodologique : Plan de prévention des risques littoraux. Ministère de l'Écologie, du Développement durable, et de l'Energie.
Meur-Férec, C., P. Deboudt, and V. Morel. 2008. Coastal risks in France: An integrated method for evaluating vulnerability. *Journal of Coastal Research* 24: 178–189. https://doi.org/10.2112/05-0609.1.
Miceli, R., I. Sotgiu, and M. Settanni. 2008. Disaster preparedness and perception of flood risk: A study in an alpine valley in Italy. *Journal of Environmental Psychology* 28: 164–173. https://doi.org/10.1016/j.jenvp.2007.10.006.
Michael, J.A. 2007. Episodic flooding and the cost of sea-level rise. *Ecological Economics* 63: 149–159. https://doi.org/10.1016/j.ecolecon.2006.10.009.
Mori, N., M. Kato, S. Kim, et al. 2014. Local amplification of storm surge by super typhoon Haiyan in Leyte gulf: Storm surge by super-typhoon Haiyan. *Geophysical Research Letters* 41: 5106–5113. https://doi.org/10.1002/2014GL060689.
Nicholls, R. 2011. Planning for the impacts of sea level rise. *Oceanography* 24: 144–157. https://doi.org/10.5670/oceanog.2011.34.
Nicholls, R.J. 2004. Coastal flooding and wetland loss in the 21st century: Changes under the SRES climate and socio-economic scenarios. *Global Environmental Change* 14: 69–86. https://doi.org/10.1016/j.gloenvcha.2003.10.007.
Nicholls, R.J., and A. Cazenave. 2010. Sea-level rise and its impact on coastal zones. *science* 328: 1517–1520.
O'Neill, E., M. Brennan, F. Brereton, and H. Shahumyan. 2015. Exploring a spatial statistical approach to quantify flood risk perception using cognitive maps. *Natural Hazards* 76: 1573–1601. https://doi.org/10.1007/s11069-014-1559-8.
O'Neill, E., F. Brereton, H. Shahumyan, and J.P. Clinch. 2016. The impact of perceived flood exposure on flood-risk perception: The role of distance: Flood-risk perception: The role of distance. *Risk Analysis* 36: 2158–2186. https://doi.org/10.1111/risa.12597.
Pagneux, E., G. Gísladóttir, and S. Jónsdóttir. 2011. Public perception of flood hazard and flood risk in Iceland: A case study in a watershed prone to ice-jam floods. *Natural Hazards* 58: 269–287. https://doi.org/10.1007/s11069-010-9665-8.
Peacock, W.G., S.D. Brody, and W. Highfield. 2005. Hurricane risk perceptions among Florida's single family homeowners. *Landscape and Urban Planning* 73: 120–135. https://doi.org/10.1016/j.landurbplan.2004.11.004.
Pearsall, H., T. Hawthorne, D. Block, et al. 2015. Exploring youth socio-spatial perceptions of higher education landscapes through sketch maps. *Journal of Geography in Higher Education* 39: 111–130. https://doi.org/10.1080/03098265.2014.1002079.
Perherin C, Azzam C, Kergadallan X (2012) Révision du guide méthodologique plans de prévention des risques littoraux: une meilleure prise en compte de l'ensemble des phénomènes pour la connaissance de l'aléa submersion marine. Congrès SHF: "Evènements extrêmes fluviaux et maritimes", Paris, 1-2 Février 2012.
Perry, R.W., M.K. Lindell, and M.R. Greene. 1982. Threat perception and public response to volcano hazard. *The Journal of Social Psychology* 116: 199–204.
Pottier, N., E. Penning-Rowsell, S. Tunstall, and G. Hubert. 2005. Land use and flood protection: Contrasting approaches and outcomes in France and in England and Wales. *Applied Geography* 25: 1–27. https://doi.org/10.1016/j.apgeog.2004.11.003.
Robin, N., F. Levoy, and O. Monfort. 2007. Bar Morphodynamic behaviour on the Ebb Delta of a macrotidal inlet (Normandy, France). *Journal of Coastal Research* 236: 1370–1378. https://doi.org/10.2112/06-0684.1.
Robin, N., F. Levoy, and O. Monfort. 2009. Short term morphodynamics of an intertidal bar on megatidal ebb delta. *Marine Geology* 260: 102–120. https://doi.org/10.1016/j.margeo.2009.02.006.
Ruin, I., J. Gaillard, and C. Lutoff. 2007. How to get there? Assessing motorists' flash flood risk perception on daily itineraries. *Environmental hazards* 7: 235–244. https://doi.org/10.1016/j.envhaz.2007.07.005.
Sabatier, F., O. Samat, A. Ullmann, and S. Suanez. 2009. Connecting large-scale coastal behaviour with coastal management of the Rhône delta. *Geomorphology* 107: 79–89. https://doi.org/10.1016/j.geomorph.2006.09.026.
Schmidt, L., C. Gomes, S. Guerreiro, and T. O'Riordan. 2014. Are we all on the same boat? The challenge of adaptation facing Portuguese coastal communities: Risk perception, trust-building and genuine participation. *Land Use Policy* 38: 355–365. https://doi.org/10.1016/j.landusepol.2013.11.008.
SHOM (2014) Références Altimétriques Maritimes. Service Hydrographique et Océanographique de la Marine, French Ministry of Defence. http://diffusion.shom.fr/pro/risques/references-verticales/referencesaltimetriques-maritimes-ram.html.
Slovic, P. 1987. Perception of risk. *Science* 236: 280.
Small, C., and R.J. Nicholls. 2003. A global analysis of human settlement in coastal zones. *Journal of Coastal Research*: 584–599.
Trumbo, C., M. Lueck, H. Marlatt, and L. Peek. 2011. The effect of proximity to hurricanes Katrina and Rita on subsequent hurricane outlook and optimistic Bias: Effect of proximity to hurricanes Katrina and Rita. *Risk Analysis* 31: 1907–1918. https://doi.org/10.1111/j.1539-6924.2011.01633.x.
Vinet, F., D. Lumbroso, S. Defossez, and L. Boissier. 2012. A comparative analysis of the loss of life during two recent floods in France: The sea surge caused by the storm Xynthia and the flash flood in Var. *Natural Hazards* 61: 1179–1201. https://doi.org/10.1007/s11069-011-9975-5.
Wolf, J. 2009. Coastal flooding: Impacts of coupled wave–surge–tide models. *Natural Hazards* 49: 241–260. https://doi.org/10.1007/s11069-008-9316-5.