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## ► To cite this version:

Colin Lemée, Oscar Navarro, Diego Restrepo-Ochoa, Denis Mercier, Ghazlane Fleury-Bahi. Protective behaviors regarding coastal flooding risk in a context of climate change. *Advances in Climate Change Research*, 2020, 10.1016/j.accre.2020.12.001 . hal-03086917

**HAL Id: hal-03086917**

**<https://hal.science/hal-03086917>**

Submitted on 13 Feb 2023

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# Protective behaviors regarding coastal flooding risk in a context of climate change

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## Abstract

The physical vulnerability of coastal areas due to rising sea level and the flooding risk consequent, does not guarantee the implementation of protective behaviors by these risk zones' inhabitants. This study aims to establish the link between the willingness to carry out protective behaviors and physical and perceived indicators of vulnerability. A typology of coastal flooding vulnerability, uses various physical indicators and their perceived counterparts which have been collected from 490 inhabitants of Cartagena (Colombia, declared world heritage of humanity by UNESCO in 1984), resident in areas of coastal flooding risks. The item-response theory (IRT) approach has been used. The results reveal that the implementation of protective behaviors is more related to perceived indicators, such as distance to the sea, than to actual physical vulnerability. We observe that physical vulnerability is linked to the intention to carry out protective behaviors. The presence of a defensive structure against coastal flooding could be considered as a visual cue and be a good predictor of the willingness to carry out protective behaviors. On the contrary, people in the most vulnerable situation (single-storey house) do not demonstrate a higher level of willingness to carry out protective behavior, as well of participants who lived in residential buildings which have demonstrated lower level of willingness to carry out such behaviors. Therefore, vulnerability of the house is not seen as a criterion that encourages participants to better protect themselves.

1

2   **Keywords:**

3   Coastal Flooding Risk; Protective behaviors; Climate change; Vulnerability; Item Response

4   Theory.

5

6

7

## 1. Introduction

Due to climate change, an increase of extreme meteorological events is expected worldwide, especially coastal flooding, defined as a temporary invasion of coastal areas by sea (Chaumillon, Bertina, Fortunato, et al., 2017). The vulnerability of coastal areas is the result of spatial inequalities, housing characteristics, the level of urban development, and the growth rates and economic vitality of the different regions (Cutter et al., 2003). Especially, an increase of the vulnerability of the Colombian Caribbean Coast to coastal flooding is expected in city of Cartagena de Indias, declared world heritage of humanity by Unesco in 1984, where urban areas were built over large sandbars. Due to sea-level rise and sediment imbalance (Rangel-Buitrago and Posada-Posada, 2013), these areas are extremely sensitive to the risk of coastal flooding during storm surges (Andrade et al., 2013). Moreover, this flooding risk results from hydrodynamic phenomena due to the arrival of heavy swell from far away and it cannot be related to local meteorological conditions (Andrade et al., 2013). Afanador et al. (2006) identified 9961 inhabitants (2314 houses) in areas at risk of coastal flooding for the city of Cartagena de Indias only.

It is commonly accepted that protective behaviors regarding flooding risk depend on the level of vulnerability of populations (Botzen et al., 2009; Cutter et al., 2003). The Extreme Intrinsic Vulnerability index developed by Creach et al. (2015) is based on four objective criteria of vulnerability: the potential water level in case of flooding, the distance between the house and a protective structure (for example, a sea wall), the type of housing, and the distance to an emergency zone. These four criteria allow to assess the objective vulnerability of inhabitants in a given area. Though, there are no established links between such criteria of objective vulnerability and intention to carry out protective behaviors in the literature.

In detail, studies demonstrated that higher protection structure is more dangerous in case of failure (Creach et al., 2015) as the time left for people to seek shelter is shorter (Vinet et al., 2012). Though, contradictory results are observed in the field of environmental psychology. It is possible that the presence of a protective structure led to a false sense of security, as it has been demonstrated by geography (Vinet et al., 2012), while other researches demonstrated that the visual presence of a protective structure (such as a sea wall) is linked to higher intentions to carry out protective behaviors (Lemée et al., 2019). In this perspective, it should be noted that individuals residing in risk areas not protected by sea walls or other structures are less likely to implement protective measures (Adeola, 2009). This idea is in line with that of Evans (2014) who, in the context of global warming, observed that individuals who were

1 aware of local cues of climate change were more inclined to put in place pro-environmental  
2 behaviors.

3 Regarding the housing type, the nature of habitat is a key indicator of vulnerability in case of  
4 flooding (Jonkman and Kelman, 2005) and Vinet (2011) has distinguished four different  
5 categories of habitat according to their dangerousness. The first category, “single-storey  
6 houses” corresponds to the most vulnerable type of habitat, as they offer little to no shelter in  
7 case of coastal flooding. This type of habitat does not offer opening on the roof and  
8 inhabitants could find themselves trapped in their houses in case of rising water. Following  
9 categories regroup houses with a partial elevation or a shelter room (category 2), houses with  
10 a full floor (category 3) or residential buildings (category 4) where the inhabitants could find a  
11 refuge in case of rising water. Although inhabitants of single-storey homes are more  
12 vulnerable (Vinet, 2011), there are no data on behavioral intentions related to this  
13 vulnerability.

14 Finally, concerning the proximity to the sea, whether it is perceived or real, it is known that  
15 living near a watercourse predicts the adoption of protective behaviors (Botzen et al., 2009).  
16 Also, Milfont et al. (2014) observed that people living near coastal areas had a greater belief  
17 in the true nature of climate change and that they provided greater support for pro-  
18 environmental government actions. Thus, in our case, perceived or physical proximity to the  
19 sea is expected to be associated to a greater level of behavioral intentions to protect  
20 themselves. However, the role of physical variables of vulnerability is not clearly established,  
21 although common sense suggests that the fact of ‘knowing’ that you are vulnerable to a risk is  
22 enough to explain the implementation of protective behaviors. Actually, this effect has not  
23 been demonstrated. The psychological variables linked to the perception of risk explain the  
24 establishment or not of protective behavior to address the risk.

25 Broadly speaking, these events will occur more frequently and, in some cases, will have a  
26 growing impact on the exposed populations, making necessary to elaborate coping strategies  
27 integrating the assessment individuals make of the risk and their willingness to take protective  
28 action accordingly. The fear of a threat would be a predictor of a habits’ change which would  
29 lead to the adoption of self-protective behaviors, such as avoidance, flight, search for  
30 information, etc. (San et al., 2010). A number of studies have demonstrated a direct relation  
31 between preventive action and risk perception (Bonaiuto et al., 2016). Cognitive and affective  
32 variables may have a role in explaining this relation (Navarro et al., 2020a; Terpstra, 2011).  
33 Regarding to affective variables, we mean psychological variables which are fundamentally

1 marked by modifications or fluctuations of the emotional state related to risks. Regarding to  
2 cognitive variables, we mean evaluative aspect that includes the judgment, memory, meanings  
3 and treatment of risk information. These two dimensions, affective and cognitive, determine  
4 decisions and actions. Research shows that in the case of coastal flooding risk in Cartagena,  
5 risk perception negatively determines the coping strategies based on emotion regulation and  
6 avoidance (Navarro et al., 2020b). In the same way, the risk perception together with self-  
7 efficiency are configured as two key variables when explaining the intention of the subjects to  
8 face anthropogenic climate change (Hidalgo and Pisano, 2010). Likewise, flooding  
9 experiences are variables that increase risk perception. The feeling of fear and the knowledge  
10 associated with the risk are significantly higher for people having a flooding experience  
11 (Guillard et al., 2019).

12  
13 The physical vulnerability of territories and housing to floods, does not guarantee that this  
14 vulnerability is fully assimilated at the individual level by the inhabitants of risk areas.  
15 Similarly, this physical vulnerability does not guarantee the implementation of protective  
16 behaviors by individuals (Navarro et al., 2020a). Consequently, if several studies in the field  
17 of geography have already proposed a list of measures to identify coastal risk areas in order to  
18 reduce the vulnerability of these cities, there is still a gap between these measures and the risk  
19 perception and the protective behaviours carried out by “naive inhabitants” (i.e. inhabitants of  
20 risk zones). The gap between institutional measures and policies, and ‘non-experts’  
21 behaviours is not surprising. Environmental risks are complex, unpredictable and non-  
22 perceptible and they are apprehended through social elaboration (Slovic, 1987, 1992). Some  
23 research shows that risk perception and place attachment, for example, explain coping  
24 strategies among residents of coastal areas (Navarro et al., 2020a, 2020b).

25  
26 Consequently, our aims are to understand how coastal risks are perceived by inhabitants of  
27 coastal areas and which are the best predictors of protective behaviours implementation. In  
28 other words, to examine the links between objective factors of vulnerability and the  
29 implementation of protective behaviours. A clear understanding of such links would be of  
30 great importance for targeted prevention policies.

1 To achieve our goal, we must find a method to predict behavior. The Item response theory  
2 (IRT) allows to study behavior prediction. According to the IRT, the probability of success of  
3 a given participant to an item, or a task, is determined by the level of ability, or willingness, of  
4 this participant on the trait being assessed, and the level of difficulty of the item, or the task  
5 (Hambleton et al., 1991). As demonstrated by Kaiser (1998), the use of the item response  
6 theory is possible in order to predict the extent to which participants will carry out certain  
7 behaviors. Indeed, Kaiser (1998) demonstrated that pro-environmental behaviors could be  
8 ordered from the easiest to the hardest and predicted with the help of the IRT. Also, IRT  
9 models are extremely useful to analyze data in the case of missing values or to compare  
10 scores across different assessments with different properties and difficulties/locations, as they  
11 provide information on the difficulty and the discriminating power of each item, or behavior.  
12 In the study of coping willingness, a few attempts already proved successful for the prediction  
13 of behaviors using IRT models (Ouyang et al., 2016; Yan and Mok, 2012).

14         Given the lack of studies on the assessment of protective behaviors using IRT models,  
15 our prime objective was to determine the pertinence of such measurement, given that to date  
16 IRT models have been successfully applied to the measurement of behaviors such as coping  
17 willingness or ecological behaviors.

18 Our second objective aims to establish the link between the willingness to carry out protective  
19 behaviors (estimated by the maximum likelihood estimate) and physical and perceived  
20 indicators of vulnerability. In detail, in the context of coastal flooding, we wanted to verify  
21 whether people's willingness to carry out protective behaviors is linked to the distance  
22 between their home and the sea, the perceived distance between their home and the sea, the  
23 type of housing and the proximity of a defensive structure against coastal flooding.

## 25         **2. Data and methods**

### 26         **2.1. Sample and participant selection**

27         The data used in this study were obtained from areas at risk of coastal flooding located  
28 in the city of Cartagena (Colombia). The sample was composed of 589 adult participants with  
29 218 males and 371 females (mean age = 43; standard deviation = 15). Participation was  
30 voluntary, and all responses were confidential and anonymous. Instructions on how to  
31 complete the questionnaire were given to the participants before they were given the  
32 statements. Details on the composition of the sample are presented in Table 1.

An ethics approval was not required for this study as per institutional and national guidelines and regulations. However, the authors have complied with APA ethical standards, in accordance with the University ethics guideline and ethics was checked at the laboratory level. Participation in the research was voluntary and informed consent was obtained from all participants.

Table 1 – Demographic characteristics of the sample ( $n = 589$ )

characteristics		$n$	Percent	Mean (years)	Standard deviation
Gender	Men	218	48.5		
	Women	371	51.4		
	Age			43	15
	Duration of residency			29	19
Professional status	Employee	245	41.9		
	Unemployed	74	12.6		
	Pensioner	55	9.4		
	Student	165	28.2		
	Housewife	31	5.3		
	Other situation	15	2.6		

## 2.2. Assessment and measures

### 2.2.1. Indicators of physical vulnerability

In accordance with previous works on the physical vulnerability of coastal territories against coastal flooding, we retained certain physical characteristics as possible predictors of the willingness to carry out protective behaviors. In detail, we retained two different indicators of distance to the sea (Table 2). A physical indicator of the proximity to the sea and its perceived counterpart (respondents had to indicate if they considered their living place as ‘very close to the sea’ ‘relatively close’ are ‘far from the sea’).

Table 2. Characteristics of the sample ( $n = 589$ ): indicators of physical vulnerability

Characteristics		$n$	Percent
Distance to the sea	Less than 100 m	160	27.4
	Between 100–500 m	345	59.2
	More than 500 m	78	13.4
Perceived distance to the sea	Close to the sea	145	24.7
	Relatively close	348	59.3
	Far from the sea	94	16.0
Presence of a defensive infrastructure	Yes	47	8.0
	No	539	92.0
Identification of a shelter in case of	Yes	213	36.2



We also investigated four different type of housing, based on the typology described in Vinet et al. (2012): ‘single-storey houses’ ‘houses with a partial elevation or a shelter room’ ‘houses with a full floor’ and ‘residential buildings’.

Finally, we investigated whether or not there were a defensive structure against flooding near the living place and the identification by the participant of a place to seek shelter, in case of flooding.

### **2.2.2. Willingness to carry out protective behaviors**

The lack of an exhaustive and practical index of the protective behaviors carried out by the inhabitants to cope with coastal flooding led us to retain the active or problem-focused coping strategies, sub-dimension of the coping scale of Lopez Vazquez and Marván (2004). Indeed, the problem-focused strategies help to keep a state of vigilance and to address the issue, whereas the emotion-focused strategies allow to avoid problems and, through this, manage psychological tension (Navarro et al., 2020). This sub-dimension of the scale is independent and describes a series of 13 protective strategies ranging from planning to housing adaptation, through active management of emotions and the search for information. It has already shown its relevance in the study of natural and technological risks (volcanic, pollution, flood) (Lopez Vazquez and Marván, 2012; Lopez Vazquez et al., 2008; Ruiz and Hernández, 2014), including flood (Navarro et al., 2016). On this sample, Cronbach’s alpha is equal to 81. It cannot be improved by suppressing items.

## **2.3. Data analysis**

### **2.3.1. IRT calibration and computation of the maximum likelihood estimate**

The IRT calibration is necessary to verify the discriminatory power of the different items, so as to retain only the most discriminatory ones and to define their hierarchical order of severity, or difficulty, if this order was not specified prior to the calibration. The discriminatory power of an item is expressed by an ‘a’ value which corresponds to the item’s strength in distinguishing respondents according to their trait levels. It is generally considered that an ‘a’ value equal or higher to 1 is necessary (Prieto et al., 2003). At this stage, it is

recommended removing items with insufficient discriminatory power in order to improve the whole model fit. At the end that should reduce the whole fit of the model. IRT calibration was performed with the Test Analysis Modules package for the R environment (Robitzsch et al., 2018).

The fscore function in the Multidimensional Item Response Theory (mirt) package for the R (mirt R) allows computing a maximum likelihood estimate for each participant. This maximum likelihood estimate takes corresponds to the level of ability of each participant in the trait being assessed, or, in the present case, to the level of willingness declared by the participant to carry out behaviors of various difficulty (Chalmers, 2012). Participants with higher scores at the different items, especially harder, the higher maximum likelihood estimates. In this case, we hypothesized that the maximum likelihood estimate, reflecting the willingness of respondents to carry out protective behaviors, would be associated to physical and perceived predictors of vulnerability. The mirt R for environment (Chalmers, 2012) was used to produce item information and maximum likelihood estimates.

### **2.3.2. Links between the willingness to carry out protective behaviors and indicators of vulnerability**

To investigate the distance to the sea, participants were regrouped into three different categories, according to the distance between their house and the coastline: ‘under 100 m’, ‘between 100–500 m’ and ‘more than 500 m’. They also had to rate their perceived distance to the sea, according to three categories: ‘very close to the sea’ ‘relatively close’ and ‘far from the sea’. ANOVA’s (analysis of variance) were performed for the two indicators in order to identify potential differences of willingness to carry out protective behaviors between the groups.

An ANOVA was also performed to investigate potential differences of willingness according to the type of housing. Concerning the existence of a defense structure near the living place and the identification of a place where participants could seek shelter in case of a flooding, a t-test was performed for each predictor.

## **3. Results**

### **3.1. IRT calibration**

The IRT calibration of this scale revealed that the different items of the scale were sufficiently loading on a single factor and that they all possessed a sufficient discriminatory power. These findings led us to retain all the different items for this study (Table 3).

Table 3. Factor loading and parameters for protective behaviors items

Items	Factor loading	Total common variance	Discriminatory power	Thresholds between response possibilities for each item	
I'm looking for information from people who know the problem	0.72	0.51	1.75	2.83	1.31
I analyze the circumstances in order to know what to do	0.51	0.26	1.01	2.64	1.20
I share my emotions with my family	0.58	0.58	1.20	2.44	0.85
I control my emotions	0.62	0.39	1.35	2.38	0.65
I make changes in my environment to avoid a disaster	0.76	0.45	1.98	2.29	1.02
I question the professionals about the problem	0.72	0.51	1.74	2.23	1.05
I face the situation directly	0.63	0.27	1.38	2.06	0.59
I try to change my lifestyle according to the problem	0.65	0.43	1.48	1.94	0.5
I set goals and redouble my efforts	0.67	0.37	1.55	1.81	0.32
I try not to rush and think before acting	0.50	0.25	0.99	1.77	0.21
I'm thinking about strategies to use	0.61	0.37	1.32	1.48	-0.05
I have my own prevention plan and I follow it	0.55	0.30	1.12	0.96	-0.43
I have my own prevention plan and I put it in place	0.52	0.26	1.04	0.86	-0.22
I am more involved in civil prevention activities	0.51	0.3	1.01	0.64	-0.47

On this basis, a maximum likelihood estimate was computed for each participant in order to account for their willingness to actively protect themselves against coastal flooding risk. This estimate takes into consideration their declared willingness to carry out the different behaviors presented, as well as the difficulty of these behaviors, determined during the IRT calibration.

### 3.2. Links between the willingness to carry out protective behaviors and indicators of vulnerability

1 An ANOVA reveals that there is no difference between inhabitants whose houses are close to  
2 the sea (under 100 m) and other inhabitants, including inhabitants whose houses are farther  
3 than 500 m ( $F(2, 580) = 0.76, p = 0.47$ ). Though, the same analysis on the perceived distance  
4 to the sea reveals that the inhabitants who perceive themselves as farthest to the sea are  
5 significantly less willing to carry out protective behaviors than other participants ( $F(2, 584) =$   
6  $7.64, p < .001$ ).

7 Another indicator of vulnerability investigated was the type of housing. The ANOVA reveals  
8 a significant difference between these groups ( $F(3, 584) = 7.05, p < .001$ ). Indeed, we observe  
9 a major difference between inhabitants of 'residential buildings' and the other type of  
10 housing. These participants declared less willingness to carry out protection behaviors.

11 Finally, we also hypothesized that the existence of a defensive infrastructure against coastal  
12 flooding, and the knowledge of a place to seek shelter in case of flooding would be  
13 accompanied by higher or lesser level of willingness to carry out protective behaviors. Results  
14 suggest that both of these indicators have an effect on this willingness. Beginning with the  
15 existence of a defensive infrastructure, it appears that people whose living place is somehow  
16 protected by some infrastructure are more willing to carry out protective behaviors than  
17 people whose living place is not protected by any infrastructure in the case of coastal flooding  
18 ( $t(1) = 1.9, p < .05$ ). Also, inhabitants who identified a place where they could seek shelter in  
19 the case of an emergency showed higher levels of willingness to carry out protective  
20 behaviors than others ( $t(1) = 5.9, p < .001$ ).

#### 22 **4. Discussion**

23 Our first objective was methodological as we aimed to verify the pertinence of an IRT  
24 approach in the study of protective behaviors. Following this first step, we investigated five  
25 different predictors of physical vulnerability to coastal flooding (physical and perceived  
26 distance to the sea, housing type, presence of a defensive infrastructure against coastal  
27 flooding and identification of a place to seek shelter in case of flooding).

28 First, this study successfully highlights the pertinence of an IRT approach in the study of  
29 protective behaviors intentions as the calibration of the active coping strategies retained all of  
30 the different strategies, as they all had a sufficient discriminatory power and were all  
31 sufficiently loading on a single continuum of willingness to carry out these strategies. The

1 computation of an estimate permitted us, then, to establish links between the level of  
2 willingness to carry out protective behaviors and indicators of physical or perceived  
3 vulnerability to coastal flooding. The use of such estimate seemed more relevant to us, as it  
4 takes into account the discriminatory power of each item (i.e. the capacity to discriminate  
5 with success participants of different levels) and its difficulty in the assessment of each  
6 participant's level of willingness, rather than a simple mean to a Likert scale.

7 Concerning the five different predictors that were investigated in this study, we observed that  
8 the physical distance to the sea is not a good predictor of the willingness to carry out  
9 protective behaviors and it appears that the perceived distance to the sea is a better predictor  
10 of these behaviors. In other words, while these results may seem surprising, they reflect the  
11 importance inhabitants give to subjective and perceived indicators in the assessment of their  
12 vulnerability and that more objective criteria are not favored. It is consistent with literature on  
13 this topic and explain the rejection regularly observed of coastal risk management policies by  
14 inhabitants of coastal areas at risk of coastal flooding (Meur-Férec and Rabuteau, 2014;  
15 Goeldner-Gianella, 2007; Goeldner-Gianella et al., 2015; Michel-Guillou and Meur-Férec,  
16 2016). In the same way, some research shows that social representations of climate change  
17 explain the differences at the level of the institutional anchoring of the climate change  
18 phenomenon in the different social and cultural contexts (Mambet et al., 2020).

19  
20 Regarding the existence of a defensive structure against coastal flood, we observe that  
21 physical vulnerability is linked to the intention to carry out protective behaviors. In this case,  
22 it appears that such structures do not give a false sense of security to inhabitants in our  
23 sample. On the contrary, our study highlights the fact that the presence of a defensive  
24 structure against coastal flooding could be considered as a visual cue and be a good predictor  
25 of the willingness to carry out protective behaviors. Qualitative interviews or further studies  
26 should confirm this hypothesis.

27 Considering the typology developed by Vinet (2011), it appears that people in the most  
28 vulnerable situation (single-storey house) do not demonstrate a higher level of willingness to  
29 carry out protective behavior. Though, participants who lived in residential buildings  
30 demonstrated lower level of willingness to carry out such behaviors. Therefore, vulnerability  
31 of the house is not seen as a criterion that encourages participants to protect themselves more.  
32 However, it appears that certain types of habitats (residential buildings), perceived as less  
33 dangerous, are accompanied by a less important willingness to carry out protective behaviors.

Different bias could explain these results, especially at a proximal level (Milfont et al., 2011), or the invulnerability bias related to the configuration of this kind of construction, in particular the buildings height.

Among the limitations of this research, the identification of a shelter near the living place as a predictor of the willingness to carry out protective behavior may be a confounded effect. Indeed, such identification could be seen as a protective behavior by itself. That being said, it would mean that the identification of a shelter near the living place would be accompanied by other protective behaviors and, if not considered as a predictor, it is linked to other defense strategies.

Another way to improve this study would be to shape the different perceived and physical indicators in order to insert them all into the same model. While we took this into consideration during the conception of the present study, it was not possible to achieve that goal.

## **5. Conclusion**

This study confirmed the hypothesis which suggests that protective behaviors and more broadly coping strategies to the risks associated with climate change, such as coastal flooding, depend in a large extent on the vulnerability assessment made by exposed individuals. Indeed, objective aspects of vulnerability, operationalized by physical characteristics such as protective structures or habitat characteristics, are not systematically linked to the implementation of these protective behaviors. In particular, habitat characteristics are not predictive of these behaviors. Place attachment studies may explain this result, as it is not the physical characteristics of the habitat but the emotional connection that we establish there that determines the experience of risk. Housing is generally experienced as a safe place “par excellence”, beyond objective characteristics. However, visual signs of threat, such as protective structures, have a better power to predict protective behavior. It may be necessary to encourage these kinds of visual signs on the public area to encourage protective behaviors. Thus, taking into account the vulnerability assessment on the part of the inhabitants becomes an obligation for public authorities, in order to better understand this complexity and improve the ways of communication, even persuasion, promoting the adoption of protective behaviors in the face of risks linked to climate changes. Some studies suggest that the catastrophic tone commonly used in the dissemination of this topic should be replaced by positive approaches

that facilitate the acceptance and participation of the general public in mitigation actions of global climate change (Pinheiro and Farias, 2015).

## Acknowledgments

This research was supported by the French National Research Agency within the framework of the CLIMATRisk project(ANR-15-CE03-0002-01).

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