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An integrative approach to study and promote natural hazards adaptive capacity: a case study of two flood-prone communities in Puerto Rico

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The risk and vulnerability literature emphasises the importance of increasing the adaptive capacity to natural hazards of exposed populations. This paper analyses the strategies of adjustment implemented by members of two flood-prone communities in Puerto Rico, and discusses how the adoption of these strategies and other factors could influence future adaptive capacity and vulnerability to floods. Semi-structured interviews with community members from different resource endowment groups were used to elicit the resources behind the process of adjustment along with additional factors that could influence future adaptive capacity, including their perceptions of risks related to floods. The analysis revealed how access to resources – including material, economic and human resources – has facilitated living with floods in these communities; although not everyone has been able to adapt in the same way. Past actions, along with public responses being undertaken in the area (i.e. flood control project and upstream structural modifications) appear to be reducing flood-risk perceptions and promoting a false sense of security among community members, irrespective of resource endowment group. For that reason, developing ways to increase awareness about future flood potential and making clear the need for complementary non-structural strategies is imperative. In short, the research findings emphasise that access to resources and cognitive factors are important determinants of adaptive capacity. Hence, both should be taken into account while developing practical strategies towards increasing adaptive capacity and reducing vulnerability to floods specifically, and to other natural hazards in general.

KEY WORDS: Puerto Rico, adaptive capacity, vulnerability, floods, semi-structured interviews, flood management

Introduction

> We have lived here a hundred years with the flood, and we can live that way a hundred years more.
>
> Resident from Maternillo, a low-income community located in the floodplain of the Fajardo River in north eastern Puerto Rico

Low-income communities in areas of high exposure are of particular interest to natural hazards researchers. Members of those communities are usually more susceptible to hazard impacts because of socioeconomic characteristics that make them less able to cope, adjust or adapt to the hazards (Morrow 1999; Mustafa 1998; Wisner *et al.* 2004). Consequently, they are considered relatively more vulnerable than communities with more access to resources that are more able to cope, adjust or adapt. In the Caribbean island of Puerto Rico, many low-income communities are settled in flood prone areas. Years of surviving floods suggest that their residents have adapted to this type of hazard, as the above quote exemplifies. But, what have been the factors that have helped residents adapt to floods? Has everyone adapted in the same way? Do current levels of adaptation better position residents to withstand future floods? What factors could influence future adaptive capacities and vulnerabilities to floods? This paper explores these questions by examining the process of flood adjustment in two flood-prone, low-income communities in Puerto Rico. More specifically, the

paper describes the strategies that have allowed residents to minimise the harmful effect of floods; identifies the factors that have influenced the implementation of such strategies; and discusses how this process and its determinants might influence future adaptive capacities and vulnerabilities to floods.

Adaptive capacity with respect to natural hazards and floods

Adaptive capacity is considered one of the three determinants of vulnerability, along with exposure and sensitivity (Polsky *et al.* 2007; Smit and Wandel 2006). Broadly, adaptive capacity refers to the potential or ability of a system (e.g. country, community, household) to make adjustments and prepare more effectively with the effects or impacts of hazards (Smit and Wandel 2006). Development in adaptive capacity research emphasises the need to contribute to practical initiatives that address and improve the capacities of communities and individuals exposed to natural hazards to deal with them (e.g. Ford and Smit 2004; Füssel and Klein 2006; Smit and Wandel 2006). Such practical application contrasts with past analyses that focused on assessments that did not necessarily investigate local situations influencing the processes by which adaptation and adjustment occur. Consequently, these earlier assessments failed to identify the needs or opportunities for proposing and implementing local initiatives (Smit and Wandel 2006). In this type of adaptation analysis, emphasis is put on the local level, particularly communities and households that are already exposed to hazards and that potentially face increased future exposure resulting from environmental change, particularly climate change (Few 2003; Parry *et al.* 2007). Here, analysis aims at documenting the ways in which communities and their members experience the changing conditions brought about by hazard events, and the processes by which they make decisions and take actions to minimise hazard impacts (Smit and Wandel 2006); in other words, the adjustment process (Parker 2000). Understanding past and current adjustments provides a means for improving adaptive capacity by identifying limitations and opportunities for that capacity (Brooks and Adger 2005).

Literature on adaptive capacity, and vulnerability reduction over the past decade has concentrated on studying the different forms, availability of and access to resources as a way of understanding what facilitates or inhibits adaptive capacity (Brooks and Adger 2005; Eakin and Lemos 2006; Smit and Pilifosova 2003; Wisner *et al.* 2004; Yohe and Tol 2002). These determinants of adaptive capacity include the various natural, material, economic, institutional, human, social, and political resources that people can draw upon to deal more effectively with hazards (Table 1). Different studies have shown the positive relationship between access to resources and the adjustments people make to withstand hazards and their adaptive capacities in relation to those hazards (e.g. Brouwer *et al.* 2007; Ford *et al.* 2008; Pelling 1997; Reid *et al.* 2007).

Other studies suggest that, frequently, availability and access to resources are not sufficient to explain adaptive capacity to natural hazards, and that cognitive factors also play an important role in determining this process (Davidson *et al.* 2003; Grothmann and Patt 2005; Grothmann and Reusswig 2006; Tobin and Montz 1997; Peacock *et al.* 2005). Cognitive factors, including higher levels of risk perception and perceived adaptive capacity, can positively influence people's motivation to adjust to natural hazards (Grothmann and Patt 2005; Grothmann and Reusswig 2006). Hence, motivation and associated cognitive factors constitute another determinant of adaptive capacity (Table 1). Cognitive factors, at the same time, may be influenced by access to resources. For instance, technical modifications that keep floodwaters from entering a house can lower risk perceptions. If such modifications efficiently minimise flood damage, then people might not feel the need to implement further strategies. Thus, the decision is not driven by lack of resources, but by the belief that additional adjustments are unnecessary. This example shows the interrelatedness of determinants of adaptive capacity and, therefore, the importance of exploring their interrelationships to understand the potential limitations to, or opportunities for, enhancing adaptive capacities. In other words, an integrative approach that takes into account both access to resources and cognitive factors is needed (Tobin and Montz 1997).

While the importance of an integrative approach has been recognised in a few studies of vulnerability and adaptive capacity to floods (e.g. Few 2003; Parker 2000), most research on community and individual (household) adaptation to floods has focused on access to resources facilitating or inhibiting adaptive capacity (Brouwer *et al.* 2007; Chan 2000; Chan and Parker 1996; Khandlhela and May 2006; Mustafa 1998 2002; Pelling 1997 1999; Rashid 2000; Winchester 2000; Zoleta-Nantes 2000). These case studies show the general relationships among limited economic, material, institutional, social, human resources and adaptive capacity, and the role of these relationships as barriers to the amount and effectiveness of measures of adjustment.

Compared to the previously cited research, case studies on the cognitive aspects of adaptation to floods are relatively fewer (Brilly and Polic 2005; Grothmann and Reusswig 2006; Ologunorisa and Adeyemo 2005; Wong and Zhao 2001). Most of these case studies address the topic of risk perception and how to reduce damages by assessing people's

Table 1 Determinants of adaptive capacity

Determinant	Description/examples
Natural resources	The resources present in the physical environment (e.g. land, mangrove, raw materials) and/or the services they provide that are useful for adaptation.
Material resources and technology	The infrastructure (e.g. transport, drainage systems, housing) and the production equipment and materials available for adaptation; along with technological systems (e.g. communications systems, protective structures) available for adaptation.
Economic resources	The economic, financial resources people have (e.g. earned income, savings, credit, pensions, remittances, transfer from the state) and that are available for adaptation options.
Human resources	The skills, knowledge, and awareness (e.g. of adaptation options, the nature and evolution of hazards), experience, ability to work, and good health that enable people to pursue adaptive strategies.
Social resources*	The social resources (e.g. informal-horizontal networks, social mobilisation, collective actions, and relations of trust, reciprocity, and exchange) upon which people can draw for adaptation.
Institutions*	The availability of critical institutions that promote and support adaptive strategies, along with the way they operate and are structured (e.g. transparent decision-making, institutional requirements).
Political resources*	Power, right, development of political capabilities or claims people can make on the state, institutions, or those more powerful than they are.
Perception/cognition	The different views of nature people have, perceptions of hazards (e.g. likelihood of occurrence and potential damage), perceived effectiveness of past adaptive actions, perceived alternatives and perceived capacity to undertake them or act upon hazard exposure.

Sources: Brooks and Adger (2005), Eakin and Lemos (2006); Reid *et al.* (2007); Tobin and Montz (1997); Wisner *et al.* (2004); Yohe and Tol (2002)

*Some sources do not distinguish between social and institutional or political capital, but refer to formal and informal networks, or vertical and horizontal relationships. This distinction is often made based on access to wider institutions from society, political factors, and processes beyond the household and community realms. Likewise, institutional and political determinants are sometimes used in conjunction, and the division depends on the nature of the claim they make.

perception about the effectiveness of large-scale flood control projects, such as dams and levees (Brilly and Polic 2005; Wong and Zhao 2001). Less discussion exists, however, on the relationship between cognitive determinants (including people's perceptions of risk and perceived adaptive capacity) and factors that influence their motivation to take action (Grothmann and Reusswig 2006; Ologunorisa and Adeyemo 2005). The danger of not exploring this multifaceted aspect of adaptive capacity is that important factors related to resource access or cognitive factors could be overlooked. Neglecting such contributors to adaptive capacity could, consequently, diminish potentially significant contributions to actions aimed at increasing the capacity of exposed populations (Grothmann and Patt 2005).

Studying adaptation and adaptive capacity to floods in Puerto Rico

Description of the study area

The study was conducted in the communities of Mansión del Sapo and Maternillo, in the north-eastern municipality of Fajardo, Puerto Rico (Figure 1). Several criteria guided the selection of these two communities. They had to be low-income and exposed to floods. Communities with this economic characteristic were identified by a list of low-income communities provided by the Puerto Rican government. Communities exposed to floods were identified in a list provided by the Federal Emergency Management Agency (FEMA) and the Puerto Rican Agency of Emergency and Disaster Management of those municipalities with recurrent flood damage. Prior to the selection of the communities, the author visited communities in some of the municipalities with most recurrent damage. The final selection was driven by access to the communities; that is, acceptance by community leaders and residents, and willingness to participate in the study.

The two communities are located in the alluvial deposits of the Fajardo River valley, within an average elevation of 3 m above sea level. They are both flanked by the river, and one of them – Maternillo – is located adjacent to the coast. The communities comprise a total area of approximately 21 ha, with Maternillo having a larger area (12.8 ha) than Mansión del

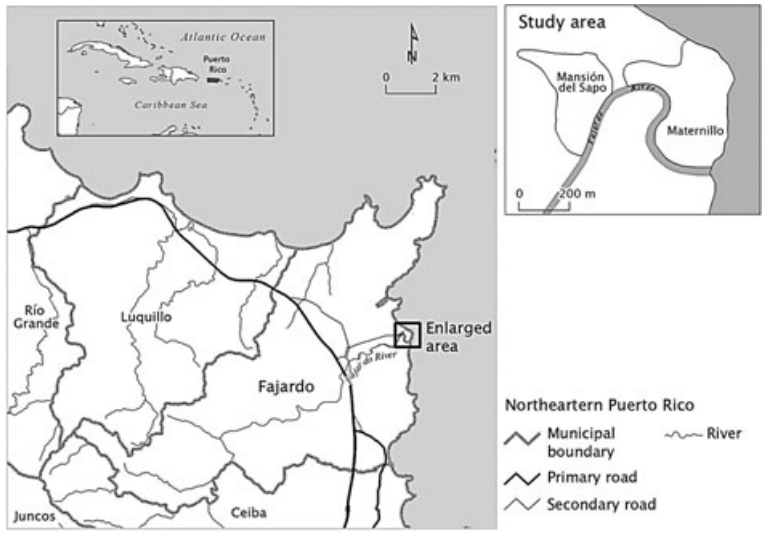

Figure 1 Location of the study area in the north eastern municipality of Fajardo, Puerto Rico

Sapo (7.8 ha). Approximately 380 and 230 people live in Maternillo and Mansión del Sapo respectively (OCE 2006).

The area has an average temperature of 26.4°C and an average mean total annual precipitation of 1575 mm. The rainy season occurs from June to November and is associated with the Atlantic hurricane season. Because of its geographic location, its topography and the influence of trade winds, it is not unusual for the area to experience heavy rainfall episodes outside the rainy season. All these factors contribute to the tendency for the area to flood, which includes rainfall and river inundations, but also floods resulting from storm surges. Approximately two to three 'minor' rainfall-driven flood events take place in the communities every year (Miguel Dávila, Maternillo's community leader, personal communication). Other than water logging of the ground, which usually lasts for about an hour and then drains, these events have no major consequences. The communities have also been subject to severe floods, usually associated with tropical storms or intense and prolonged rainfall periods. Two of the major flood events experienced by them over the past 20 years were associated with Hurricane Hugo in 1989, and with an intense rainfall event that occurred outside the rainy season on 6 January 1992. The flood resulting from Hurricane Hugo is remembered by community members as the most intense and damaging one. It is estimated that Hugo brought about 200 mm of precipitation to the area (Scatena and Larsen 1991). Floodwaters resulted from a combination of river overflow and storm surge. Both communities were flooded, and most structures (except those that were sufficiently elevated) were affected. Flood waters rose by almost one and a half metres inside some houses, and the inundation lasted approximately 10 h (Miguel Dávila, personal communication). The flood of 1992 resulted from river inundation brought about by approximately 280 mm of intense rainfall. The flood occurred at night and caught many of the residents by surprise. Only about one third of the houses in Maternillo were flooded, but most houses in Mansión del Sapo were affected. In some areas, the water rose about 1 m, and the inundation lasted about 5 h. The most recent major flood occurred on 17 April 2003 as a result of river encroachment due to intense rainfall (approximately 305 mm). Compared with the floods of 1989 and 1992, this flood lasted only 2–3 h, water did not rise as high, and floodwaters only affected the lower lying houses.

The foundation of the communities dates back to the first decades of the 1900s. Originally, the area was part of a mangrove system. In 1914, a small settlement of approximately a dozen houses started to develop, composed mainly of workers at the port that supported the sugar cane industry (González-Vélez 2003). The settlement continued to expand because of the creation of parallel economic activities related to local coal production and fishing. Around 1928, the removal of mangroves became more aggressive; lands were filled and occupied by the local labourers, especially sugar cane plantation field workers, limestone quarrymen and fishermen. Subsequent mangrove removal and land filling towards the ocean allowed further human settlement. By mid-1960, about 100

families lived in the area (Rivera-Rivera 2002). The closing of the Sugar Cane Company in the 1970s, and the resulting decline of the port activities, resulted in a slowdown of the area's economic activities and growth, a process that continues today (Rivera-Rivera 2002). At present, the communities are considered to be fishing communities, although many of their residents work in manufacturing and the service sector (González-Vélez 2003).

The Puerto Rican government has formally classified Mansión del Sapo and Maternillo as 'special communities', a government characterisation used to identify low-income communities for development assistance. Based on a socioeconomic study of communities in the Fajardo municipality, 30% of the households in Mansión del Sapo live on less than US$500 a month, 41.3% of the working force are unemployed, 61% of the households are led by single mothers, 29% of the young population (25 years or younger) have not completed high school, and 4% of the population are illiterate (OCE 2006). Similarly, 31% of Maternillo's population live on less than US$500 a month, 38.6% are unemployed, and 3.4% are illiterate, while 34% of the households are headed by single mothers and 61.7% of the young population have not completed high school (OCE 2006). None of the residents of Mansión del Sapo have land tenure, and many of the houses are in substandard condition whereas some of Maternillo's residents possess land tenure, and housing conditions are better compared with those of Mansión del Sapo (Fuller-Marvell 2002).

Participants and data collection

A total of 36 households, 18 from each community, were selected to participate in this study. This number represents approximately 24% of the households from both communities.

The possession-based method (Takasaki *et al.* 2000) was used to select a stratified random sample of households by resource endowment, allowing comparisons between groups. Overall, there were 12 randomly selected households in each resource endowment group: poor, intermediate and rich. The resource-endowment classification is relative to other community members and is not comparable to any absolute definition of poverty. A detailed explanation of participant selection by resource endowment group is given in López-Marrero (2008).

Semi-structured interviews at the household level were used to elicit participants' flood adjustment processes, along with their perceptions of flood-associated risks. Interviews have been employed in case studies exploring the processes of adjustment and response to floods at the local level (e.g. Chan and Parker 1996; Wong and Zhao 2001; Zoleta-Nantes 2000). Thirty-six semi-structured interviews were conducted between June and September 2006. The interviews took place in the homes of the participants, where the heads of the households were interviewed. Interviews were conducted in Spanish and lasted from 1 to 3 h and all were conducted by the author. The interview questions elicited information on floods in general, rather than on any particular flood event. Interview questions were open-ended and designed primarily to obtain qualitative information. In some instances (i.e. strategies' effectiveness, flood risk perception), questions had a quantitative component.

The first part of the interview focused on asking participants about the anticipatory and responsive strategies that they had developed to reduce the harmful effects of floods, that is, their flood adjustment processes, and the factors that had facilitated the implementation of these strategies. Participants were then asked to score the effectiveness of these strategies in minimising the negative effects of floods, ranging from 0 (ineffective) to 5 (completely effective). Next, participants were asked if they considered implementing other strategies to minimise the negative effects of floods, and if so, what strategies they considered necessary. This question was followed by questions about the barriers households faced to undertake such strategies. When participants did not consider implementing further strategies, they were asked to explain their reasoning.

The second part of the interview focused on questions related to risk perceptions of floods and how these perceptions have changed over time, along with the factors influencing changes in risk perceptions. In this study, 'risk of floods' referred to the extent to which participants perceived floods as a threat to their lives, property, or things they value; this concept combined potential occurrence of floods with associated damages. In this last part of the interview, participants were asked to score their perceived level of risk of floods using a value of 0 (none) to 5 (high) relative to the past, present, and future. After completing this scoring, participants were asked to explain the reasons for their scores and the factors that influenced changes in their perceived risk over time.

The analysis of the interview data consisted of categorisation, coding and generation of descriptive statistics. Coding assisted the interpretation of the qualitative information obtained from the interviews (Cope 2006; Dunn 2000). Responses about the factors facilitating or inhibiting the implementation of strategies were coded, based on the general determinants of adaptive capacity. The factors influencing changes in risk perception over time were similarly coded. Basic descriptive statistics were used to analyse the quantitative portions of the interview. Mean values were calculated for the scores on the level of effectiveness of the strategies employed and on the levels of per-

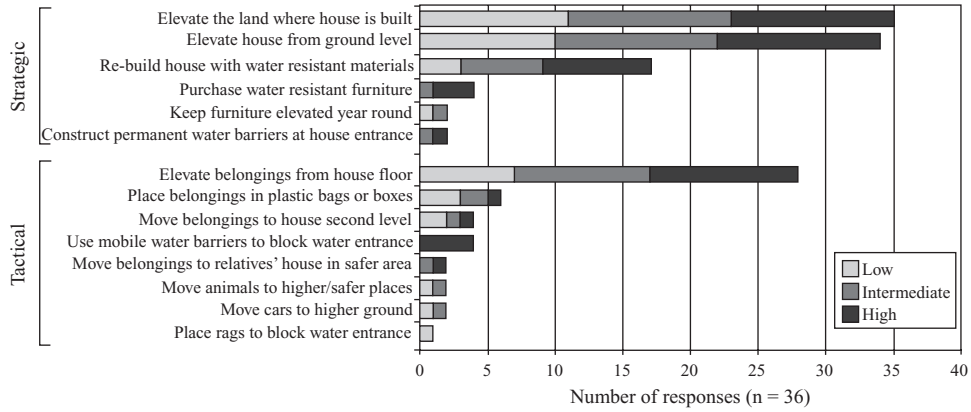

Figure 2 Types of anticipatory adjustments to deal with flood hazards, divided into strategic and tactical strategies; shown for the three resource endowment groups

ceived flood risk over time. To investigate further the differences between groups, data were analysed in general terms (all participants) and based on the three wealth-endowment groups (poor, intermediate and rich).

Understanding household adjustments to and risk assessments of floods

Anticipatory strategies of adjustment to flood hazards

In both communities, the interaction of several determinants of adaptive capacity facilitates reducing the harmful effects of floods. Anticipatory-strategic (long-term) strategies were the most commonly cited actions that successfully allow participants to adjust to floods. Filling the land where houses were built was the preferred individual strategy.

> It was different in the past. I used to live in a house at ground level. It was horrible, everything used to get damaged. Then we built on filled land, and now it has to be raining a lot for water to get into the house.
>
> Female participant from Maternillo

The strategy, which involves access to material/technological, economic, and institutional resources, is undertaken by nearly all of the participants (98%) from all three resource endowment groups (Figure 2). Land filling occurred most heavily until the 1970s, when the municipal government provided fills to individuals requesting it. This government practice was discontinued during the early 1990s. Today, residents who continue filling their land need the financial resources to buy land fill or connections with people who provide fill for free.

Along with land filling, residents successfully reduce their exposure and the negative effects of floods by structurally raising their houses. This strategy, mentioned by 95% of the participants, is used by households in all three resource endowment groups. The manner of elevating the house varies, however, among residents from different groups. Tactics include constructing the house on a concrete platform, using stilts of different heights and materials, and raising the house on bricks. The technique used depends on the economic, institutional, and human resources (i.e. construction skills) to which participants have access.

The strategy of raising one's house is often related to the third most common type of adjustment: re-building the house with more water-resistant materials. In most cases, house improvements, in terms of both elevation and water-resistant materials, is a reaction to recurring damage from floods and hurricanes. About half of the participants mentioned this third strategy, and these people were mainly from the 'high' and 'intermediate' resource endowment groups (Figure 2). Usually, individuals with more economic resources also have the connections to get institutional support (government aid), whereas those with fewer economic resources and social connections are less able to carry out such strategies.

> I used to live in a house made of wood and zinc, at ground level. Now I feel safer since I built my house in cement and stilts. I built the house using my own means and with aid provided by the government.
>
> Male participant from Maternillo

There are other less-cited strategic strategies that only individuals with appropriate economic means can undertake. These include buying water-resistant

furniture and constructing barriers to prevent water entrance into their house.

Along with the anticipatory-strategic strategies, participants mentioned anticipatory-tactical strategies they use to minimise negative floods effects (Figure 2). Tactical strategies are short-term actions undertaken shortly before or during hazard occurrence (Smit *et al*. 1999). The most cited strategy of this type is to elevate belongings from ground level, which was mentioned by 78% of the participants from all resource endowment groups. Here, human resources, especially household number and health, constitute an important determinant of adaptive capacity. Participants not mentioning this strategy use similar ones, such as moving belongings to safer places (e.g. second stories, higher land, or relatives' houses) or placing belongings in plastic bags or boxes (Figure 2). One strategy mentioned by only four participants from the 'high' endowment category was to use mobile water barriers, which entails gluing wood panels to the entrances of the house. This strategy, albeit costly, was described as being very effective by those using it.

Although strategies varied among participants, each of them thought their respective strategies were effective. On a scale of 0–5, the mean value for all strategies was 4.0. Levels of effectiveness were similar among resource endowment groups, with slightly lower effectiveness expressed by participants from the 'intermediate' group (low = 4.2, intermediate = 3.4, high = 4.5). Participants declared that elevating the land and the house had successfully reduced flood exposure and damage. These strategies have been effective for small to medium floods, when floodwaters inundate community roads and house yards. In such cases, only those houses that are not elevated get flooded, and these households elevate their belongings to minimise damage. The question remains whether these strategies will be effective during extreme floods, such as those projected under future climate change conditions.

As demonstrated, participants were generally satisfied with the effectiveness of their anticipatory strategies. Nonetheless, some participants (39%) expressed the need (and desire) to make additional adjustments. These strategies, which mainly require access to material resources, include some type of technical fix, such as improving the condition of the house, building permanent water barriers in and around the house, and constructing a second floor (Table 2). Fourteen participants expressed their desire to implement these strategies, and 10 of these individuals belonged to the 'low' resource endowment group. Barriers to using such strategies relate to having few economic resources or lacking the networks needed to obtain government aid. A few other participants mentioned that the lack of construction skills or construction permits prevented them from using these technical adjustments.

Table 2 Strategies of adjustment to reduce flood damage and barriers to the implementation of these strategies, as understood by community members

Strategy	Barriers to implement strategy
Improve housing conditions	Lack of economic resources, no credit, inability to work, no government aid, no construction skills, no construction permits, personal preferences
Build permanent water barriers	Lack of economic resources
Construct a second level	Lack of economic resources
Move/secure more belongings when floods are imminent	Bad health, small household number, no preparation time, single parent, minors to attend, live alone, inappropriate behaviour
Move from the community to a non-flooding area	Lack of economic resources, personal preferences

The desire to raise and secure belongings when floods are imminent, or to move to a place beyond the flood zone, were two other strategies identified by some participants (Table 2). These strategies, however, were mentioned by fewer participants (eight and five, respectively). Barriers to raising and securing belongings related to a lack of human resources, such as bad health, small household numbers, single parent status, and having minors to attend. There were, additionally, some behavioural barriers associated with the inability of performing this strategy, including the perception that floods do not constitute a 'real' danger and not wanting to spend the time and effort needed to raise and secure belongings. The latter constitute what Grothmann and Patt (2005) identify as 'high perceived adaptation costs', which could lower adaptive capacity.

Responsive strategies of adjustment to flood hazards

Responsive strategies, ones undertaken after hazard occurrence, were also commonly discussed by participants. Indeed, responsive strategies involving human and social resources; including family and neighbours' assistance, along with aid, were viewed

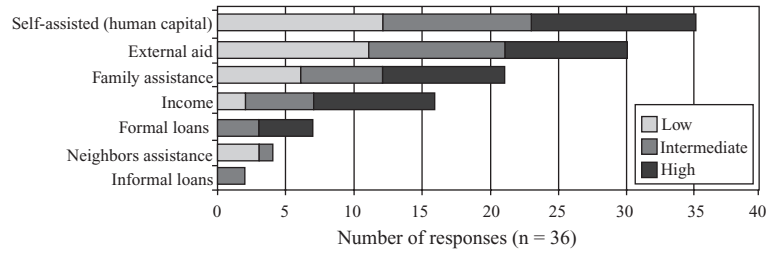

Figure 3 Means of conducting responsive strategies for dealing with flood hazards, shown for the three resource endowment groups

as essential after flood occurrence (Figure 3). All but one participant explained how household members worked together to 'return to normal' after flood events. Specifically, household members clean up and reorganise belongings. Households with more and healthier family members have an advantage over those households composed of few, old and sick members. However, external aid (including cash and material provisions from the federal, national, and municipal governments, along with aid from churches, voluntary groups, and NGOs) was mentioned by more than three quarters of the participants as one of the most important elements of their response and recovery (Figure 3). In this case, institutional resources determine responsive adjustment to floods in the study area. Many participants asserted that, without this aid, they would be unable to recover fully.

> Without governmental aid I would be desperate; I could not fully recover. And things will get worse as people say governmental aid would be less and less in the future.
>
> Female participant from Maternillo

In these instances, participants were asked what they would do without this external aid. Most of them do not have an alternative plan, although they did express concern over how aid is distributed and about potential decreases in government aid in the future. Many expressed the view that, if aid was not given, households with savings, credit, or extended family that could assist them economically (which is not the case for most residents) would be the ones able to respond and recover after a damaging flood event. Income and formal loans were also discussed. These strategies were mentioned by less than half of the participants, with most coming from the 'high' resource endowment group (44% and 19% for income and formal loans, respectively).

Social resources – the various relationships of trust and reciprocity that enable people to act collectively (Adger 2003) – were also mentioned as an important responsive strategy at the community level. More than half of the participants (58%) indicated that the help system based on extended family and kinship relationships was a significant source of support during and after flood occurrence. Assistance includes moral support, help in cleaning up, and provision of cash, food and household equipment. Social networks also include assistance from neighbours, mainly in helping to secure belongings (before flood occurrence) and to clean up (in the aftermath). Some participants (6%) depend on friends within the community for informal cash loans. Nonetheless, although it is still present in times of crises like floods, participants described mutual help between community members and collective actions as declining in comparison to the past, when social networks were stronger and more people relied on each other. Technological adaptations, institutional support, aid, and even the changing social conditions in the communities (López-Marrero and Yarnal 2010) appear to be contributing to the weakening, if not the replacement, of social capital.

> In the past people used to help each other more, when there was less external aid and assistance. There used to be more solidarity. Now there are a lot of new people around, and with the many problems related to drugs and crime people live frightened. We do not share as much as we used to.
>
> Female participant from Maternillo

Compared with the effectiveness of anticipatory strategies, participants found responsive actions less useful (mean values for all participants = 2.0, with values of 2.1, 1.7, and 2.2 for participants of the 'low', 'intermediate' and 'high' resource endowment groups, respectively). This was particularly true for external aid distribution. Participants expressed discontent with the fact that aid was not available all the time and that its distribution was not equal for all affected people. In fact, aid has been a source of conflict between community members because not everyone received it, or it is not distributed in accordance with

Table 3 Rank-ordered factors for not pursuing additional strategies to minimise the negative effects of floods

Factor	Number of responses
House is sufficiently elevated and constructed with water-resistant materials	9
Frequency and intensity of floods will decrease in the future	7
Floods are part of nature and there is nothing people can do about them	4
Feeling of security (experience, knowledge, divine protection)	4
Barriers constructed in the house to block water entry	2

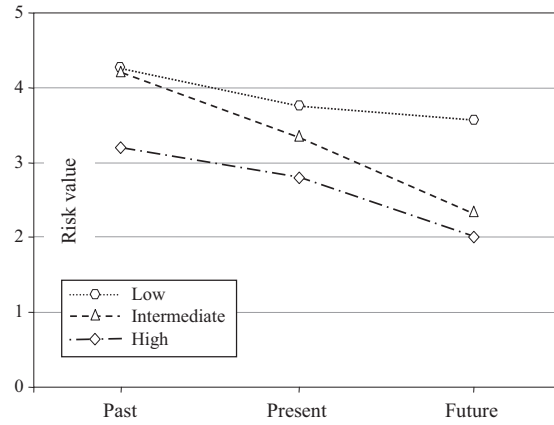

Figure 4 Mean perceived risk values and their change over time for the three resource endowments groups

damage (sometimes households that are least affected receive more aid). Some participants claimed that the political and institutional networks of community members influenced aid distribution. Here, equity, or lack thereof, affects responsive actions. Finally, participants described how aid, even when available, did not always compensate for loss. They also expressed concern over future availability and distribution of aid. For these reasons, they preferred to implement as many anticipatory strategies as they could so that they did not need to rely on external-responsive ones.

Flood-hazard risk perception

In Maternillo and Mansión del Sapo, more than half of the study participants (61%) assessed their adjustments as effective and sufficient for flood mitigation. In fact, approximately half of them thought that they did not need to undertake any other strategy at all. The factors influencing this perception are shown in Table 3, with the main reason attributed to past house improvements (i.e. elevation and construction materials).

> I don't think I have to do anything else. Now the house is well constructed – in cement and at higher ground. I am positive water will not get into the house.
>
> Male participant from Mansión del Sapo

This result is quite surprising. Although it is evident that technical modifications to houses have helped reduce the negative effect of floods, it is also true that this strategy has not completely eliminated household flood exposure and damage. For instance, in 1989 when hurricane Hugo landed on the north-eastern coast of Puerto Rico, floodwaters inundated the majority of the houses in the communities. Likewise, the flood of January 1992 flooded more than half of their homes. In spite of having experienced these events, and partly in response to the fact that they had not witnessed major floods lately, participants expressed the belief that the frequency and intensity of floods would decrease in the future. Also, the belief that floods are part of nature, and that nothing much can be done but to 'learn to live with them', is another factor influencing participants' perceptions that no further strategies are needed (Table 3). These findings constitute examples of how cognitive factors could reduce adaptive capacity in the communities because of low motivation for engaging in adaptive strategies.

Cognitive factors that may influence adaptive capacity are also evident in the decreasing trends in flood-risk perception over time. More than three quarters of the participants judged risk as having been higher in the past (mean = 3.9). In fact, more than half expressed the highest risk value for the past (median = 5). Perceptions of contemporary risk were lower (mean = 3.3), and the distribution of values is more dispersed around middle values (median = 3.5). Risk perception continued to decrease when referring to the future (mean = 3.0), with fewer high values and increasing numbers of low values (less than 2), and more zero values (i.e. no risk at all). There are differences when comparing the three resource endowment groups. In all periods, mean values of risk perception are higher for the 'low' resource endowment group, and progressively lower for the 'intermediate' and 'high' group (Figure 4). This result is consistent with the effectiveness of strategies as expressed by participants from the different resource endowment groups, as described above. Despite these between-group differences, the decreasing trend in risk perception over time is true for the three of them.

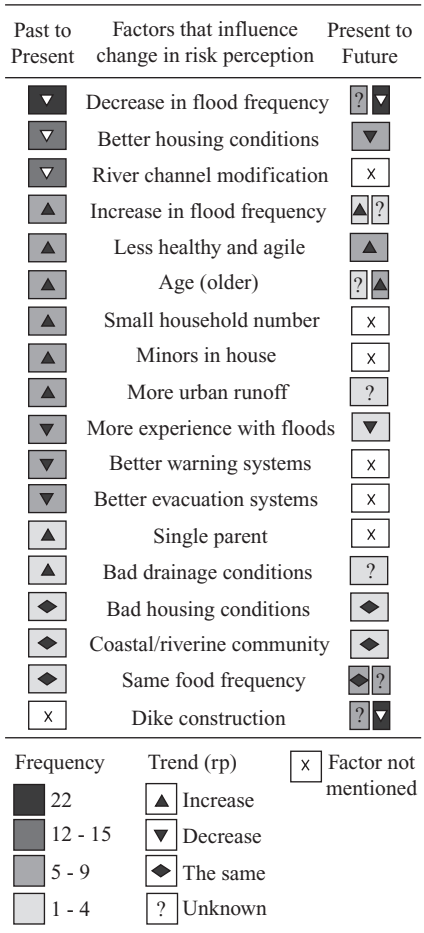

Figure 5 Expressed change in flood-risk perception (rp) during two periods, including factors influencing changes in risk perceptions. The cell lightness indicates the frequency with which each factor was mentioned. The arrows indicate the changing trend of risks perceived over time. For the second time period (present to future), there are some cases with two cells for a single factor, which represents two trends given by participants for that factor

Two main sets of factors appear to influence the decreasing trend in risk perception over time (Figure 5). They are related to two of the determinants of vulnerability: exposure and adaptive capacity. About 60% of the participants perceived a decrease in flood frequency and, therefore, a decrease in exposure. They also observed that rainfall had decreased over time. In addition, they attributed decreasing floods to one type of public adaptation in the area – the modification of the river channel and surrounding topography due to road construction upstream.

> By modifying the river up there [upstream] floods have diminished.
>
> Male participant from Mansión del Sapo

As described by participants, these modifications cause floodwater to lose its force before reaching the communities. Additionally, being more prepared, having more experience with floods, and having better and more efficient warning and evacuation systems are also factors that influence trends in lower risk perception.

While there is a general tendency of decreasing risk perception when the present is compared with the past, some participants (31%) expressed the opposite view; that is, the risk today is greater than that in the past. Others (22%) saw the risks as equal between the two periods (Figure 5). For those perceiving higher risk, increased flood exposure, both because of increased urban runoff and bad drainage conditions, is an influencing factor. In addition, decreasing access to human resources – health, age, and household number – is an important element.

> I even used to get excited seeing the flood; I was young, I could get more water out of the house, I could manage better. I am not that young and healthy any more, plus we are now less people at home.
>
> Female participant from Maternillo

Those noticing no change in risk over time cited bad housing conditions and similar levels of exposure (due to similar flood frequency and geographic location) as key factors.

Comparing the present with the future, 42% of the participants consistently saw future risks as being lower than current risks, while 33% perceived similar risks. In contrast, 17% did not know what to expect in the future, and 8% judged that risk would be higher. For those reporting lower future risk, decreasing flood exposure is again a determining factor for their response. Here, however, decreasing exposure was not linked to an expected decline in precipitation, but to the construction of dikes in the Fajardo River as a way to prevent community flooding.

> The dikes will solve the flood problem. If they are built, risk will be minimal.
>
> Female participant from Mansión del Sapo

This structural strategy, a government project that is currently being implemented, is key to the understanding of future risks in these two communities. Those expecting no change in risk based their assessment on their unaltered geographic location; being a coastal community and with the Fajardo River flanking them, they felt flood exposure and associated risk will always be present. Other participants who were

undecided about future flood frequencies and risks referred to uncertainty with respect to the termination and maintenance of the dike, the maintenance of drainage systems, and the generation of runoff from nearby urban areas.

> If the dikes are built, risk to floods could be less; but if built up areas nearby keep increasing things could become worse. With all that construction and clogged drainages, water can not flow naturally and could flood the community.
>
> Male participant from Mansión del Sapo

Finally, the main reason for those perceiving higher future risks was decreasing human resources – older household members with deteriorating health – and, consequently, a shrinking capacity to deal effectively with future floods.

Discussion

The implementation of various strategies of adjustment has allowed community members of Mansión del Sapo and Maternillo to 'live with floods'. What is needed now is to increase this capacity; that is, to augment their 'coping range' (Smit and Wandel 2006) to accommodate future floods that may exceed current ranges. The findings from this study suggest that enhancing adaptive capacity to floods depends on at least six actions: increasing access to resources that promote adaptive capacity, particularly for those members that are in less advantageous socioeconomic situations; promoting collective actions that go beyond individual household actions; increasing social memory; addressing the cognitive and motivational factors that promote adaptive strategies; improving awareness of rising levels of risk; and reducing psychological reliance on structural adjustments.

The results from the interviews demonstrate how interrelationships among the determinants of adaptive capacity permit flood adaptation. Particularly, access to material and technological resources have led to the reduction of the harmful effects of floods by enabling technical improvements to be made to land and houses. Not everyone, however, has been able to implement these strategies because of unequal access to resources. Clearly, inequity reduces adaptive capacity. In the case of Puerto Rico, government involvement in providing construction materials or access to loans is an action that could help to decrease the vulnerability of housing to floods. Additionally, there is an urgent need to maintain and promote social resources that have permitted adaptation, but that appear to be eroding today. While it is true that technology and external aid have increased adaptive capacity, there is no guarantee that these factors will always be available to everyone. Participants noted the lack of access to economic resources as the main obstacle to undertaking more effective adjustments. The rising costs of material and technological strategies, the economic insecurity and unstable sources of income, and the highly politicised and inequitable environment that characterise the study area (López-Marrero and Yarnal 2010) could limit adaptive capacity and increase vulnerability. Social resources, if developed efficiently and sustained over time, provide an alternate, 'low economic-cost' means for dealing with natural hazards and lowering risk (Wisner *et al.* 2004).

Community organisation and collective action are, for instance, essential for enhancing adaptive capacity in these two communities. Pelling (1997) showed how community organisation to clean and maintain drainage conditions, as well as to develop collective-help systems for building elevated houses, successfully decreased flood exposure and impacts in poor communities in urban Guyana. In the present study, community organisation and the creation of local committees could foster local initiatives aimed at decreasing flood exposure and damage. Such initiatives do not require substantial economic resources. In Mansión del Sapo and Maternillo, community cooperation and action could encourage regular cleaning of drains and canals, as well as reduce the trash problem confronted in the communities – problems identified by community members as causes of local floods (López-Marrero 2008). The challenge of promoting collective action in these communities is one of overcoming trends of decreasing human and social capital, a situation reflected in the interviews. In this case, initiating local initiatives might involve initial outside assistance and incentives, which Zoleta-Nantes (2000) suggests as requirements for attempts to reduce flood impacts in poor urban settlements in the Philippines.

Increasing social memory of flood occurrence is another action needed to enhance adaptive capacity. In Mansión del Sapo and Maternillo, there is no shared record of such memory, only in the minds of those that have experienced extreme flood events. Documentation could fill this gap, with records of the times when extreme floods occurred, what happened before, during, and after these events, how people dealt with them, and what did or did not work in terms of minimising flood damages. An inventory of floods and flood responses is particularly cogent due to the changing conditions of the communities; that is, one characterised by new members, young people and immigrants who may never have experienced extreme floods. Enhancing social memory, in terms of both flood occurrence and traditional adjustments, has been effective in reminding residents of flood-prone areas about flood risk and the necessity to take precautions to diminish damage (Wong and Zhao

2001). Social memory can be documented and 'stored' in different ways, including oral history, storytelling and films, all of which have proven to be important educational means for promoting local involvement in the reduction of natural hazard vulnerability (Davis and Hall 1999). Discussing social memories about hazard occurrence has proven to be an effective way of building awareness, consensus and motivation for local risk and vulnerability reduction in other Caribbean settings (Thompson and Gaviria 2004).

Although access to resources will certainly influence adaptive capacity in these two communities, cognitive and motivational factors could represent potential barriers to future adaptation to floods. Adaptive capacity will not be successful unless there is a willingness to adapt among those affected (Brooks and Adger 2005). Motivation, in turn, is influenced by perception of risks, perception of effectiveness of past adjustments and reliance on public hazard protection (Grothmann and Patt 2005; Grothmann and Reusswig 2006). As the findings of this study illustrate, these three motivational factors do indeed undermine future adaptation in the two communities.

Adapting successfully to floods requires being aware not only of the means to which damage could be avoided, but also of the flood hazard itself (Parker 2000). In Mansión del Sapo and Maternillo, a perceived decrease in precipitation and flood occurrence influenced the degree to which residents judged future flood risks. Precipitation in eastern Puerto Rico has declined (Heartsill-Scalley *et al.* 2007), and climate change is likely to bring drier climates to the island (Neelin *et al.* 2006). However, some climate models predict that global climate change might lead to a warming of the Atlantic Ocean, which is likely to increase the intensity and frequency of tropical cyclones (Bengtsson *et al.* 1997; Knutson and Tuleya 2004), a trend that could result in significantly higher peak precipitation rates. In this case, the intensity and frequency of extreme precipitation events could amplify the current intensity and frequency of floods. Therefore, to counteract the perception of decreasing flood risk among residents, it seems vital to build awareness and understanding that extreme flood events could intensify in the future. Education and community awareness need to go beyond what floods are, how to secure property, and where to get assistance, which are the types of information currently provided in pamphlets available to the public. While this educational information is important and necessary, more information on floods is needed. For instance, it is also important to stress the fact that floods in this area are phenomena related not only to precipitation trends and riverine floods, but also to other factors, such as urban runoff and coastal storm surge, both of which are likely to increase. Processes such as sea level rise and storm surges under different climate scenarios are other examples of information that ought to be available to community members. Some notions of the complex drivers of floods are already present in the community (López-Marrero 2008). What is currently lacking is a concentrated effort to expand this existing knowledge by presenting additional information in a way that is accessible to a wide audience.

Perceived effectiveness of past actions and reliance on public flood protection are two aspects that, along with the apparent decrease in precipitation and flood occurrence, could lower motivation among residents and, therefore, their adaptive capacity. As Grothmann and Reusswig (2006) argue, individual and community initiatives to implement measures to minimise flood damage will be perceived as redundant if public adaptations are undertaken. The construction of the dike along the Fajardo River was an important factor influencing lower values of risk perception. Although it is true that the construction of this dike will decrease flood exposure in these communities, it is also true that the structure may create a false sense of security among the population that increases vulnerability to the most extreme events. In Mansión del Sapo and Maternillo, public risk communication must state clearly that dike construction does not provide total security, that such projects cannot eliminate floods completely, and that they can fail (and have failed in the past). Making these points clear to residents, and increasing their understanding of how these structural projects function, may remind them of the importance of implementing other adaptation strategies.

Conclusions

This paper highlights strategies implemented by members from two flood-prone communities of northeastern Puerto Rico to minimise the harmful effects of floods. It has attempted to understand how today's actions and other human processes may influence future adaptive capacity. The response to future climate risks will likely be facilitated by past and present adjustments (Brooks and Adger 2005). Following this statement, the analysis of the process of adjustment to floods in Mansión del Sapo and Maternillo suggests that access to economic, technical, institutional, social and human resources will facilitate (or undermine) future adaptive capacity to floods. In fact, just by looking at the socioeconomic profile of these communities, one could surmise that the lack of economic resources (and associated lack of other types of resources) is what constrains community members' adaptive capacity. If the analysis of adaptive capacity were limited only to access to resources, there would be little to do other than increasing peoples' economic resources or diminishing inequity

gaps – goals that, albeit important, would be difficult to attain, at least in the short term.

Adding cognitive factors to the study of adaptive capacity suggests very practical and relatively easy-to-implement strategies to reduce flood vulnerability. As the study findings demonstrate, cognitive factors related to decreasing trends in precipitation and flood occurrence, to perceived high efficiency of past strategies, and to reliance on public flood protection, all reduced the perceived risks associated with future floods. Such a sense of security curtails the willingness of people to continue undertaking current strategies or to implement new ones. For that reason, practical adaptation strategies include building awareness of possible extreme flood occurrence due to climate change and enhancing public risk perception about the functioning of structural flood control projects; stressing these projects does not eliminate completely flood exposure. Lessons learned in this study suggest that an integrative approach that includes both access to resources and cognitive factors could enhance adaptive capacity by proposing practical initiatives in flood-prone areas.

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