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ORIGINAL PAPER

Identifying factors influencing flood mitigation at the local level in Texas and Florida: the role of organizational capacity

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Abstract In the United States, mitigating the adverse impacts of flooding has increasingly become the responsibility of local decision makers. Despite the importance of understanding why flood mitigation techniques are implemented at the local level, few empirical studies have been conducted over the last decade. Our study addresses this lack of research by examining the factors influencing local communities to adopt both structural and non-structural flood mitigation strategies. We use statistical models to predict multiple flood mitigation techniques implemented by cities and counties based on a survey of floodplain administrators and planning officials across Texas and Florida. Particular attention is paid to the role of organizational capacity to address floods in addition to various local geophysical and socioeconomic characteristics. Results indicate that organizational capacity is a significant factor contributing to the implementation of both structural and non-structural flood mitigation techniques, even when controlling for contextual characteristics.

Keywords Flood mitigation · Organizational capacity · Texas · Florida

1 Introduction

Local communities in the United States (U.S.) are increasingly bearing the responsibility for repetitive flood problems. By adopting and implementing both structural and non-structural mitigation measures, localities are taking important steps to reduce property damage and human casualties associated with localized flood events. No longer the flood control and avoidance is the sole province of the federal government. Instead, effective flood mitigation lies in the hands of county commissions, zoning boards, mayors, planning departments, and other local governmental entities. The twenty-first century vehicles for

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preventing loss of property and life may not be based only on federal disaster relief, but also on county- and citywide land use plans, development and construction codes, zoning and subdivision ordinances, and community-based outreach programs.

With the adoption of the National Flood Insurance Act of 1968 came an added responsibility for local jurisdictions to manage and regulate areas vulnerable to flooding to reduce future losses. Under this Act, participating communities can purchase federal insurance against flood loss in exchange for the adoption and enforcement of a floodplain management ordinance to reduce future flood risk to new construction in floodplains. More recently, federal incentive programs have been added, such as FEMA's community rating system (CRS), where participating jurisdictions earn premium discounts on their federal flood insurance in exchange for adopting various flood mitigation strategies. States have also addressed the flooding problems by enacting local requirements, such as building codes, impact assessments, land use restrictions, and other standards. Today, it can be argued that the greatest opportunity to reduce the risks to and impacts from chronic flood hazards rests in the hands of local decision makers.

Despite the importance of flood mitigation at the local level, few large-scale empirical studies on how and why mitigation techniques are implemented by localities have been conducted in the U.S. over the last decade. Extensive research has been done on the degree to which flood (and other natural hazards) policies are integrated into local comprehensive plans (see for example, Burby et al. 1985, 1997; Burby 1998; Godschalk et al. 1989; Brody 2003a), but these studies rarely consider whether the policies are actually implemented and enforced. In fact, a disconnection between plan content and policy implementation has been documented in several studies (Brody and Highfield 2005). A better understanding of the local conditions under which flood mitigation is most likely to take place may foster the development of more flood-resilient communities in the future.

Our study addresses this lack of research by identifying the factors influencing the extent and type of flood mitigation among local jurisdictions in coastal Texas and Florida. Specifically, we examine the effects of multiple local geophysical and socioeconomic characteristics on both structural and non-structural mitigation strategies. Particular attention is paid to the role of organizational capacity and commitment to address floods in enabling the development of better prepared and more resilient communities. We use statistical models to predict 19 flood mitigation techniques implemented by cities and counties based on a survey of floodplain administrators and planning officials across Texas and Florida. Results from our study provide valuable information on organizational characteristics and specific local conditions influence the degree to which flood mitigation is occurring at the local level, as well as highlights important differences in effort between TX and FL. Systematically evaluating flood mitigation at the local level also provides policy signals to decision makers in other states on how best to craft a program that can most effectively reduce the adverse impacts of floods over the long term.

The following section reviews the various structural and non-structural techniques available to decision makers to reduce flooding risks. Next, we identify the importance of strong organizational capacity for effective mitigation and identify specific testable hypotheses. Then, we describe our study area, sample selection, variable measurement, and analytical procedures. Results are reported in two phases. First, we correlate individual measures of organizational capacity with flood mitigation techniques. Second, using multiple regression analysis, we isolate the effects of organizational capacity on the implementation of structural and non-structural mitigation techniques while controlling for several geophysical and socioeconomic control variables. Then, we interpret our findings and discuss their policy implications for establishing flood reduction programs at the local level. Finally, we propose an agenda for future research on examining the motivation for and consequences of implementing local flood mitigation policies and better understanding how planners can minimize the rising costs of floods nationwide.

2 Structural and non-structural flood mitigation techniques

Flood hazard mitigation can be broadly divided into structural and non-structural approaches according to whether engineering or administrative methods are employed (Thampapillai and Musgrave 1985; Smith 1996). Structural approaches are generally based on engineering interventions to control floods or protecting human settlements by building seawalls, levees, channels, and revetments. In contrast, non-structural approaches are based on adjustment of human activities and communities to mitigate flood damage with measures such as directing land use away from hazardous areas, communicating mitigation information, protecting sensitive areas, and insurance schemes to distribute risk (Alexander 1993; Few 2003). In many cases, a complement of both structural and non-structural mitigation strategies is used under a single jurisdictional flood program.

2.1 Structural approaches

The history of flood mitigation in the U.S. has been dominated by structural techniques, beginning with the Mississippi River flood in 1927 (Birkland et al. 2003). Succeeding this event, the federal government's Flood Control Act of 1930 supported national programs of structural flood control works. Structures which involve modification of the built environment to mitigate flood damage include levees, floodwalls, and fills. Another structural method applies channel phase and land phase to control floods (Alexander 1993). Structures in channel phase include dams, dykes, reservoirs and methods for accelerating or retarding flows, reducing bed roughness and deepening, and straightening or widening channels. Structural methods in land phase include gully control, modified cropping practices, soil conservation, revegetation, and slope stabilization (Alexander 1993).

Structural approaches to flood mitigation have benefits when it comes to reducing or preventing flood damages. According to the U.S. Army Corps of Engineers, while flood damages from 1991 to 2000 totaled $45 billion dollars, flood control measures prevented over $208 billion dollars of damage (USACE 2006). However, beginning as early as the 1950s, researchers began to discover the limitations of structural approaches to flood mitigation. First, excessive flooding can exceed the design capacity of a structure resulting in significantly higher flood damages than if the area had been unprotected (White 1945, 1975; Burby et al. 1985; Stein et al. 2000; Larson and Pasencia 2001). Nowhere was this more apparent than in New Orleans, Louisiana shortly after the landfall of Hurricane Katrina, where large areas of the city were destroyed because of the failure and breaches of the levees and flood walls protecting the city due to poor maintenance and design failure. Second, structures like channels or levees can raise the level of the river, increasing the flood pulse downstream and the velocity of the water by constricting the waterway and the natural floodplain, thus shortening flooding time and resulting in greater downstream flooding (Birkland et al. 2003). Third, structural solutions can bring a false sense of security to the public (Dalton and Burby 1994; White 1936). The belief that areas protected by flood control works are completely safe can encourage new developments in floodplains, which increase the risk of mortality and property loss (Burby et al. 1985). Fourth, structural measures are often erected with high financial and environmental costs. For example, the USACE has spent over $100 billion dollars (1999 dollars) since the 1940s on structural flood protection projects nationwide (Stein et al. 2000). Finally, the construction of dams and other flood control structures contributes to adverse environmental impacts, such as the decline of fish and wildlife habitats, water quality, and function of hydrological systems (Abell 1999; Birkland et al. 2003).

2.2 Non-structural approaches

In light of the potential negative effects of structural approaches to flood mitigation, localities are increasing adopting non-structural techniques as the basis of their flood programs. These strategies include insurance programs, land use planning tools, education and awareness, environmentally sensitive area protection, and other emergency and recovery policies for mitigating flood loss. The most widely implemented non-structural flood mitigation technique is the National Flood Insurance Program (NFIP), established in 1968 as an attempt to stem rising flood losses in the U.S. The NFIP is responsible for providing insurance to those living in vulnerable areas as long as local jurisdictions adopt some minimum level of protection. However, effectiveness of the NFIP has been repeatedly criticized for encouraging floodplain development and generating repetitive losses with high financial costs (Godschalk et al. 1999; Platt 1999).

In order to address rapidly expanding urban and suburban development patterns that can place residents in areas vulnerable to flooding, communities are also implementing spatially targeted land use planning policies. The concept of integrating hazard mitigation into land use planning frameworks has a long history. Several scholars, beginning with White (1936), have argued that loss of property and human life could be minimized through sound local land use planning techniques (Burby et al. 1985, 1999; Godschalk et al. 1989). Land use policies and regulations, such as development restrictions, clustering, density bonuses, and transfer of development rights, can reduce the negative impacts of flood events by directing growth away from susceptible areas. Proactive land use planning strategies that steer development away from vulnerable areas can not only reduce flood damage, but also protect critical natural habitats and water quality. Also, reducing the footprint of impervious surfaces across regions will help in maintaining the structure and function of key hydrological systems (Whipple 1998). For example, local plans that contain policies for raising density requirements to cluster development in least vulnerable areas can help to avoid property damage from future flood events. These types of provisions are often found in local plans, zoning ordinances, land development codes, and construction codes.

Other non-structural approaches to flood mitigation often complement traditional land use policies. These include public education, technical assistance, taxation and fiscal policies, flood warning, and forecasting. Education can include printed materials, websites, training workshops, etc. Fiscal strategies can involve a referendum to dedicate funding for flood mitigation programs or to acquire lands that are particularly sensitive to flood damage. Another type of fiscal strategy is to obtain government funding, such as through the Community Block Grant Program, where federal funds can be allocated to local jurisdictions for specific flood mitigation initiatives. Finally, flood warning and forecasting strategies are commonly used by local governments to gather data, assess structures, and predict the consequences of flood events. Various computer models and assessment software can help guide communities looking at riverine flooding, retention, and storm drainage. Local flood mitigation programs usually involve a mixture of different non-structural techniques that when combined help fortify communities against repetitive flood events. Despite the range of available land use planning and other tools, early studies showed that when mitigating floods, local governments primarily resorted to basic zoning and subdivision ordinances as opposed to policies involving land acquisition, financial incentives, or public facilities (Burby and French 1981; Burby et al. 1985; Olshansky and Kartez 1998).

3 Role of organizational capacity

The extent of both structural and non-structural flood mitigation policies is thought to be influenced by the capacity of the organization implementing the adopted strategies. In the plan evaluation literature, capacity is usually measured as the number of planning staff members devoted to drafting a local plan. However, this narrow interpretation of capacity misses many of the characteristics that enable public entities to make informed decisions. In this study, we take a broader, more inclusive look at the organizational capacity, drawing from the literature and past studies on the topic. Capacity, in this sense, can be conceptualized as the ability to anticipate flooding, make informed decisions about mitigation, and implement effective policies (Honadle 1981). Key characteristics of organizational capacity include financial resources, staffing, technical expertise, communication and information sharing, leadership, and a commitment to flood protection (Hartvelt and Okun 1991; Grindle and Hilderbrand 1995; Hartig et al. 1995; Handmer 1996). This conceptualization of organizational capacity is not only based solely on funding or the amount of technical expertise, but also on the ability of individuals within an unit to work together to achieve a common goal.

Organizational capacity thus constitutes a foundation on which strong flood mitigation programs rest. For example, previous studies have found that increasing numbers of planning staff and amounts of financial resources, with which to carry out a program, will lead to higher quality mitigation policies (Burby and May 1998). The higher the planning agency capacity for a given jurisdiction, the more technical expertise and personnel can be devoted to implementing flood mitigation techniques (Olshansky and Kartez 1998; Brody 2003b; Laurian et al. 2004). Greater financial resources can lead to more extensive engineering approaches to mitigation or community-wide programs to prepare residents for flooding events.

The level of commitment is also an important factor underlying a strong local flood management program. A local government may have the resources to develop a flood mitigation program, but lack of commitment from both staff and elected officials could lead to failure in the implementation of policies (Handmer 1996; Ivey et al. 2002). Numerous studies (Dalton and Burby 1994; Berke et al. 1996; Burby et al. 1997; Brody 2003a) have emphasized local governmental commitment associated with natural hazards, such as floods, as a key factor in the implementation of mitigation strategies. Strong organizational commitment to flood protection should lead to the implementation of more flood mitigation strategies because agencies will emphasize the importance of reducing the adverse impacts of floods during planning processes.[1]

Another important characteristic of local organizational capacity for flood mitigation is the ability to adjust policies in response to a flood-related problem. Planners and floodplain

[1] While past studies have analyzed capacity and commitment as separate variables, we combine these two concepts into one measure for two reasons. First, the modern organizational design literature often considers commitment a component of capacity. Second, the two variables are so highly correlated statistically, that we could not analyze them in the same equation due to very high levels of multicollinearity.

administrators must be flexible in their decisions to accommodate changing conditions of the built environment, sudden shifts in local interests, and a steady stream of new and often conflicting information. Hazard mitigation plans and policies thus need to be adaptive instruments, geared toward uncertainty and surprise, with reasoned expectations about how existing conditions will respond to management actions (Holling 1996). For example, development prohibitions in flood-prone areas can be designed in an experimental fashion. If a policy succeeds in meeting its objectives, expectations are affirmed and human safety is protected. If the policy fails, an adaptive design still permits learning so that future decisions can proceed from a better base of understanding. In its broadest sense, adaptive approaches to management ensures that organizations responsible for adopting plans are responsive to variations in the ecological and human system and are able to react quickly with effective management tools and techniques (Westley 1995; Handmer 1996).

Of course, public organizations do not operate alone, but within a larger community composed of a network of stakeholders, complex relationships, and collective human values (Brody 2008). Flood mitigation policies are usually adopted and implemented through a collaborative process involving multiple contributing actors. The groups include other government entities, as well as private and non-government interests. Stakeholder groups and individuals can bring valuable knowledge and innovative ideas about their community that can increase the quality of adopted plans and better ensure their implementation. It is often argued that stakeholder collaboration can act as a powerful lever for generating trust, credibility, and commitment to the implementation of policies (Innes 1996; Wondolleck and Yaffee 2000). Collaborative activities within and among organizations include sharing of data and information, communication, establishment of informal networks, and joint project management (Ivey et al. 2002).

Based on the premise that strong capacity will enable an organization to better prepare for and cope with natural hazards, we seek to test the following overarching hypothesis:

H1: Higher levels of local government organizational capacity will lead to more extensive implementation of structural and non-structural flood mitigation policies, while controlling for socioeconomic and geophysical variables.

Organizational capacity is, in reality, composed of several sub-variables, each with its own potential effect on local mitigation. For example, *collaboration-based* variables include strong communication, sharing information, and pooling of resources across organizational units. *Competency* variables contributing to organizational capacity include number of staff, level of funding, quality of data, and the ability to retain personnel over the long term. Finally, there is an *individual characteristic* component to organizational capacity, such as personal commitment to flood mitigation, strong leadership within the organization, ability to think and act long range, and to see the interplay between human and natural systems. Each one of these facets of organizational capacity can contribute to the degree of local flood mitigation.

4 Methods

4.1 Study area

We selected coastal Texas and Florida as the study areas to examine organizational capacity and local flood mitigation strategies for several reasons. First, both states border the Gulf of Mexico, are extremely prone to coastal flooding, and are actively engaged in different types of local level flood mitigation strategies. For example, Texas consistently incurs the most deaths (double the total for the second highest state, California) and insurance losses per year from flooding than any other state in the U.S. According to the Federal Emergency Management Agency's (FEMA) statistics on flood insurance payments from 1978 to 2001, Texas reported approximately $2.25 billion dollars in property loss. These losses amount to more than California, New York, and Florida (the next three states on the list of the most property damage) combined (NFIP 2007). Florida also experiences significant annual economic losses from floods due to its low elevation, large coastal population, and frequent storm events. Based on a composite risk score accounting for floodplain area, population, and household values, Florida ranked the highest among all states for flooding risk (FEMA 1997).

Second, while both states are among the most susceptible to flooding and flood damage, their different policy settings and development patterns allow for a useful comparative analysis. For example, Florida adopted a statewide mandate requiring all local jurisdictions to adopt a legally binding, prescriptive comprehensive plan with the passage of the Florida Growth Management Act in 1985 (Chapin et al. 2007). Under this requirement, cities and counties within the state must adopt in their plans specific flood mitigation and coastal natural hazard policies. Specifically, localities must include in their plans policies that protect flood plains and limit development in and direct populations away from "coastal high-hazard areas" (CHHAs) (Deyel et al. 2008). Despite this "checklist" approach to land use planning, there continues to be wide disparity in the breadth and quality of environmental policies within local plans in Florida (see Brody 2003c).

In contrast, Texas has no comparable state-level planning mandate. Coastal Texas and Florida also have very dissimilar population growth and development histories requiring different types of mitigation techniques. For example, on both coasts, Florida has experienced rapid urban and suburban development over the last several decades to the extent that several of its counties are essentially built-out. On the other hand, coastal Texas has yet to experience the same degree of growth, except for the Houston–Galveston metropolitan region. Most of the Texas coast is relatively undeveloped so that the watersheds are hydrologically more intact compared to Florida. While coastal Texas has a relatively small percent of the total U.S. coastal population, the Gulf coast region population is expected to increase by over 40% between the year 2000 and 2015 (Texas State Data Center 2008). These major differences in the conditions of each state create an ideal setting in which to examine the variation in local flood mitigation policies along the Gulf of Mexico.

4.2 Sample selection

Our sampling frame was based on the 2000 U.S. Census listing of "place names." We selected local jurisdictions with populations equal to or greater than 5,000 residents for all of Florida and for those jurisdictions intersecting fourth-order hydrological units (as defined by the USGS) within 100 miles of the Texas coastline. In both states, we excluded from analysis the jurisdictions located on the islands.

We surveyed the lead planner or planning director for each jurisdiction in Florida and the designated Floodplain Administrator (FPA), the administrative equivalent, in coastal Texas. The survey instrument consisted of a self-administered web-based questionnaire, distributed in early 2006 via e-mail as a cover letter with a link to the survey's website where respondents could enter a code specific to their jurisdiction to complete the survey.

Survey implementation followed the Dillman's three-tiered approach for survey mailings (Dillman 2000). The initial survey distribution was followed with a reminder letter sent to the respondents' e-mail addresses after 1 month. If no response was received after 2 months, e-mails and cover letters were re-sent. Follow-up reminders were sent via e-mail unless the respondent requested a paper copy of the survey. We mailed the survey in paper format to 50 jurisdictions because we either did not have e-mail or Internet contact information or these jurisdictions had policies preventing their participation in web-based surveys. In total, we sampled 471 jurisdictions, 264 in Florida, and 207 in Texas. The cooperation rates for the two states were 35.2% and 38.6%, respectively, allowing us to analyze a sample of 173 local jurisdictions. Due to missing values associated with specific mitigation strategies, the sample size for multiple regression analyses was reduced to 88 jurisdictions.

4.3 Variable measurement

We measured the implementation of flood mitigation strategies using low ordinal scales. Respondents were asked a series of questions on their use of various structural and non-structural mitigation techniques over the last 5 years on a scale from 0 to 2, where 0 is never used and 2 is used extensively. The following five structural variables were measured: retention/detention, levees, channelization, dams, and clearing of debris. Fourteen non-structural variables were measured, including zoning measures, setbacks, technical assistance, construction codes, etc. By summing the observed scores of individual flood reduction strategies, we created two dependent variables: *structural mitigation and non-structural mitigation*. As a test of scale reliability, we computed a Cronbachs Alpha for each index. Structural and non-structural mitigation coefficients were 0.63 and 0.82, respectively. A complete list of all mitigation measures is described in Appendix A.

Through the survey, we measured 13 indicators of organizational capacity for flood mitigation on 0–5 ordinal scale, where 0 is not present and 5 is very strong. Indicators include commitment, communication, information sharing, financial resources, available staff, data quality, policy adjustment ability, etc. (a complete list of organizational capacity indicators is found in Appendix A). An overall estimate of the depth of organizational capacity was measured by summing the observed scores for all capacity variables, where a Cronbachs Alpha coefficient of 0.94 indicated strong scale reliability. This measure is used as the primary independent variable in the regression models.

In order to better isolate the effect of organizational capacity on the implementation of flood mitigation strategies, we also measured and analyzed several control variables. First, we included the percent of a jurisdiction's land area that is within the 100-year floodplain. In some instances, large floodplain areas could lead to more extensive mitigation techniques to ensure vulnerable residents are protected from the adverse impacts of floods (Burby and French 1981). On the other hand, a greater percentage of floodplains could restrict development in these areas to the degree that mitigation strategies are not needed (Godschalk et al. 1999). In addition to a geophysical variable, we also measured flood history predictors to ascertain the influence of hazard experience on survey responses. The logic behind including flood history variables in our analysis is based on previous studies which show that damaging events trigger mitigation responses from the government (Dalton and Burby 1994; Burby et al. 1997; Correia et al. 1998; Haque 2000; Simonovic and Ahmad 2005). However, this effect may depend on the type of previous hazard experience in a community. For example, Godschalk et al. (1989) found storm history a positive influence on mitigation activities, but recent storm damage a negative predictor. Similarly, Burby et al. (1997) noted in their empirical study that the previous occurrence of a natural disaster did not have a strong effect on the number of mitigation techniques adopted by communities. Kartez and Faupel (1995) suggested that it takes 5–10 years for mitigation strategies to become institutionalized following a major disaster event. Due to these divergent findings, we included two hazard experience variables in our statistical models: a jurisdiction-experienced damaging flood event in the most recent year and the total dollar amount of insurance claims (in millions of dollars) under the NFIP over the 5-year period preceding the survey (to match when mitigation strategies were being reported by respondents). Together, these variables capture the influence of both recent and long-term cumulative impacts from the previous flooding events.

We also measured several socioeconomic independent variables. First, we measured the median household income for each jurisdiction based on aggregating census block group information. We used a similar method to calculate the level of education in each jurisdiction based on the percent of the population receiving a bachelor's degree or higher for those 25 years of age or older. Finally, using Census data, we measured a population change variable from 1990 to 2000. We assumed that more educated and wealthy localities under pressures from population growth would be more likely to implement both structural and non-structural mitigation strategies. Lastly, we measured the state in which each jurisdiction in the sample is located as a dichotomous variable. As described above, Florida and Texas have very different policy settings, regulatory requirements, and development patterns that may influence the degree of and extent to which flood mitigation techniques are implemented. A large body of past research support state planning mandates as a regulatory lever for increasing the quality of local planning activities (see, among others: Burby et al. 1997; Deyle and Smith 1998). A complete listing of variables and their operations is included in Table 1.

4.4 Data analysis

We analyzed the data in two phases. First, we used Pearson's product–moment correlation coefficients to test the association between each organizational capacity indicator and flood mitigation strategies. This analytical step provided initial evidence on the linkage between strong organizational capacity and the implementation of structural and non-structural mitigation techniques. Second, we conducted two ordinary least squares (OLS) multiple regression analyses where structural and non-structural mitigation strategies were the dependent variables. Tests for model misspecification and spatial autocorrelation did not reveal any violations of OLS assumptions. We did, however, detect heteroscedasticity in the model predicting non-structural mitigation leading us to analyze the equation with robust standard errors to correct for this potential bias. We also found multicollinearity among the population and income variables described in Table 1, requiring us to remove them from the final analyzed model.

5 Results

Based on the results of the correlation analysis (Table 2), we find a strong statistical link between high organizational capacity and the implementation of structural and non-structural mitigation strategies. In general, local organizational capacity is more important for using non-structural techniques, which involve a greater degree of collaboration among multiple parties to effectively implement. For example, staff commitment to planning for flood-resilient communities is more significantly correlated with non-structural approaches ($p < 0.01$) such as land use policies than more engineering-based interventions. Also,

Table 1 Measurement of variables

Variable	Type	Measurement	Scale	Source and years of data
Structural mitigation	Dependent	Sum of five mitigation techniques on a 0–5 scale	0–25	Survey
Nonstructural mitigation	Dependent	Sum of 15 mitigation techniques on a 0–5 scale	0–75	Survey
Organizational capacity	Independent	Sum of 13 characteristics on a 0–5 scale	0–65	Survey
Floodplain %	Independent	Area of 100-year floodplain/area of jurisdiction	0–1	FEMA digital Q3 flood data
Recent flood event	Independent	Number of years from the time of survey to most recent damaging flood event	0–18	Survey
Five year flood loss	Independent	Sum of NFIP flood loss damage claims from 2001 to 2005 divided by 1 million	0–568.6 million	FEMA/NFIP
Income	Independent	Median household income	\$19,469–\$130,721	U.S. Census
Education	Independent	Percent bachelor's degree or higher among population 25 years of age or older	4.8–79.4	U.S. Census
Population change	Independent	Percent change from Year 1990 population to 2000 population	1.56–57.24	U.S. Census
State	Independent	TX = 0; FL = 1	0/1	U.S. Census

Table 2 Relationships between organizational capacity characteristics and mitigation strategies

	Structural mitigation	Non-structural mitigation
Organizational capacity	0.32**	0.45**
Commitment	0.19	0.41**
Sharing information	0.23*	0.40**
Verbal communication	0.39**	0.32**
Sharing resources	0.07	0.30**
Networks	0.14	0.30**
Leadership	0.31**	0.28**
Financial resources	0.27**	0.26*
Available staff	0.30**	0.34**
Data quality	0.24*	0.34**
Adjustable policies	0.34**	0.27**
Long range planning	0.35**	0.36**
Human ecology	0.39**	0.48**
Hire and retain staff	0.26*	0.32**

* $p < 0.05$, ** $p < 0.01$

while information sharing among staff members appears statistically significant for both approaches ($p < 0.05$), the correlation is much stronger for non-structural ($p < 0.01$) approaches, which includes education, training, and collaborative agreements (see Appendix A).

The different effect of organizational capacity on structural versus non-structural flood mitigation strategies is particularly evident when it comes to sharing financial and personnel resources among staff members (in the same organization and in other organizations within the jurisdiction). Structural interventions are not significantly correlated (since presumably these initiatives come from one organizational source), whereas non-structural activities are highly significant ($p < 0.01$) since multiple parties are often involved. Overall, because of the process-oriented, collaborative requirements of non-structural flood mitigation, relationships among people appear particularly important. The establishment of informal or personal networks among staff members also follows the same statistical pattern in this indicator, and is statistically significant for non-structural techniques ($p < 0.05$) but not for structural. Available staff members who remain in their positions for the long-term and high quality data are other organizational traits correlated more strongly with non-structural versus structural flood mitigation strategies. The one characteristic of organizational capacity that favors the implementation of structural mitigation initiatives is available financial resources to plan effectively for a flood-resilient community. Engineering solutions are usually more expensive than those efforts rooted in planning and education, and thus require greater amounts of funding to accomplish.

As an aggregate measure, organizational capacity remains a statistically significant predictor of increased flood mitigation strategies in Texas and Florida even when controlling for various contextual variables. Table 3 shows the results of multiple regression analysis predicting structural flood mitigation. A unit increase in organizational capacity corresponds with a significant increase in the extent to which structural measures are implemented to reduce the adverse impacts of floods ($p < 0.01$). The percentage of floodplain area within a jurisdiction is also significant, but the effect is negative ($p < 0.01$). Local communities in both states appear to be using less structural mitigation techniques in

Table 3 Modeling structural flood mitigation strategies

Variable	Coefficient	Std. error	*t*-value	Significance	Beta
Organizational capacity	0.0446	0.0155	2.87	0.005	0.3070
State	0.5353	0.4264	1.26	0.213	0.1367
Floodplain (%)	−0.0285	0.0093	−3.05	0.003	−0.3261
Education	0.1740	0.3480	0.50	0.618	0.0525
Five year flood loss	0.0007	0.0025	0.29	0.770	0.0297
Recent flood event	−0.1668	0.0878	−1.90	0.061	−0.1956
Constant	2.7207	0.8790	3.10	0.003	
Adjusted R^2	0.1472				
n	88				

areas most vulnerable to flooding. While the total amount of property loss claimed over the study period does not seem to trigger the adoption of structural mitigation efforts, more recent damaging flood events correspond to a higher use of structural techniques ($p < 0.1$). That is, as the number of years from the time of the survey to the most recent flood event increases, the less likely a jurisdiction will use structural mitigation techniques.

As shown in Table 4, organizational capacity has an equally strong effect on the implementation of non-structural mitigation strategies at the local level. In this model, the state in which these initiatives are being implemented is statistically relevant. Florida uses significantly more ($p < 0.01$) non-structural measures to mitigate floods compared to Texas, which relies more heavily on engineering-based approaches. Education is also a major driver of non-structural mitigation ($p < 0.01$). A more educated public may be more receptive to strategies that involve information dissemination, training, and voter-supported projects. In fact, based on the standardized betas, education is the strongest predictor of non-structural mitigation techniques, more so than the two flood history variables combined. In this model, the most recent year of a damaging flood event has a little effect on the dependent variable. Instead, total losses from floods over the past 5 years is a significant positive predictor of non-structural mitigation strategies where $p < 0.05$. It should also be noted that, in general, our predictive power and overall model fit is much stronger when explaining non-structural versus structural mitigation efforts at the local level.

Table 4 Modeling non-structural flood mitigation strategies

Variable	Coefficient	Std. error	*t*-value	Significance	Beta
Organizational capacity	0.1208	0.0413	2.92	0.004	0.2830
State	3.7574	1.1370	3.30	0.001	0.3268
Floodplain (%)	−0.0235	0.0208	−1.13	0.261	−0.0916
Education	3.3210	0.8831	3.76	0.000	0.3415
Five year flood loss	0.0118	0.0047	2.52	0.014	0.1584
Recent flood event	0.0393	0.1348	0.29	0.771	0.0157
Constant	6.2143	2.3905	2.60	0.011	
R^2	0.4096				
n	88				

6 Discussion

Based on the results of our study, local government organizational capacity is a critical component for reducing the impacts of flood events at the local level. In fact, the degree to which an organization responsible for flood management possesses the resources, expertise, and culture to mitigate the adverse impacts of floods appears as or more important than past disaster experience, geophysical conditions, and the state in which planning is taking place. Given the importance of collaboration, expertise, financial resources, and other characteristics comprising organizational capacity, building capable organizations must be a priority for local decision makers interested in protecting their communities from flood-related disasters. Thus, state and regional entities should not only focus solely on encouraging localities to adopt mitigation strategies, but also on facilitating the development of strong and enduring public organizations. It is important to note that enhancing local organizational capacity does not always need to be a costly endeavor. The individual components stemming from the literature and described in Appendix A suggest that fostering a culture of information sharing, communication, and flexibility is equally as important as financial resources.

In addition to showing the criticality of organizational capacity in facilitating the development of resilient communities in Texas and Florida, our analysis also reveals other factors driving the implementation of local flood mitigation strategies. First, jurisdictions with large percentages of 100-year floodplains within their boundaries implement fewer flood mitigation strategies, particularly those we classified as structural. We interpret this finding as a positive signal that local decision makers are guiding development away from the floodplain and therefore have less of a need to mitigate potential disasters. Local jurisdictions with large floodplain area may also have less land available for development or people living in the floodplain, reducing mitigation requirements. Another explanation may be that large public engineering projects are less politically or financially feasible in vulnerable areas, and thus act as a deterrent for structural more than non-structural mitigation initiatives. Particularly, the financial requirements for building dams, channelizing waterways, etc., may be too much of a burden on local government entities. Directing development away from floodplains may not only helps avoid costly property damage, but also reduce the need for mitigation strategies that may be difficult and time consuming to implement.

While the percentage of floodplains within a jurisdiction does not significantly correlate with non-structural mitigation techniques, we find that the state political and regulatory climate is a major factor leading to more extensive implementation of this category of activities. Florida implements significantly more non-structural measures most likely because it has a much stronger planning tradition, where by mandate localities must adopt a comprehensive plan that addresses flooding issues. Land use planning often involves zoning, land acquisition, protected areas, education, and other activities that are considered as non-structural approaches to flood mitigation. Our findings corroborate past studies, which suggest state-level mandates foster better-prepared and more resilient local communities. We also argue that local public officials and residents in Florida are more engaged in proactive planning for floods and less tolerant of property damage and human casualties resulting from flood events, leading localities to implement a more extensive array of mitigation strategies. For example, an analysis of participation in FEMA's CRS, which provides incentives for local jurisdictions to engage in non-structural mitigation activities, shows that Florida obtains scores, on average, two times higher than that of Texas. This finding provides evidence that Florida is far more prepared to mitigate floods than Texas. A greater commitment to planning and preparedness at the state level may thus lead to more extensive mitigation strategies at the local level, resulting in decreased property damage and human casualties resulting from floods.

The education level of community residents also drives the implementation of non-structural flood mitigation techniques. An educated public is more likely to be receptive to and supportive of training, targeted education, training, and referendums for specific flood mitigation projects. They may also be more aware of the long-term benefits of non-structural approaches and the past failure of structural approaches highlighted in the media during hurricanes and large tropical storms in both states. Making both formal and informal education a priority may also, in this case, lead to more extensive implementation of non-structural flood mitigation initiatives.

Finally, our analysis demonstrates that prior flood experience influences the implementation of flood mitigation strategies in different ways. For example, more recent damaging flood events appear to trigger structural mitigation, whereas a longer history of repetitive flood loss drives non-structural techniques. We explain this difference through the timing of local response associated with flood mitigation. Structural approaches are more likely to occur as a reactionary intervention to a single flood event. Clearing of debris, channelization, and small dams are often quick responses that require little public input or large-scale planning. In contrast, a long-term history of flood damage will more likely spur non-structural strategies requiring more time and public commitment to adopt and implement. In general, non-structural mitigation policies tend to be focused more on a long-term change of behavior rather than making quick gains in response to a recent event. Indeed, even a 10-year record of flood damage is also strongly correlated with the use of non-structural mitigation techniques. Better understanding and institutionalizing the chronic nature of coastal flooding along the Gulf coast may thus be critical for decision makers to implement policies that shape the way communities develop over the long run and ensure they become places resilient to the adverse effects of meteorologically driven hazards.

7 Conclusion

Our study empirically reveals the importance of strong organizational capacity in the implementation of local flood mitigation strategies. Building capable, adaptive, and collaborative public decision-making institutions may be just as important for protecting communities along the Gulf of Mexico than state regulatory mandates, socioeconomic conditions, and physical vulnerability to floods. While this research systematically and quantitatively demonstrates the effectiveness of strong and cohesive organizations, it should be considered only as an initial step in examining the overall topic. First, future studies should include larger samples over multiple states. We could only investigate less than a hundred local jurisdictions across two states, reducing our ability to externalize the results beyond the Gulf of Mexico. Second, larger sample sizes would permit a greater number of control variables to better isolate the effect of organizational capacity on flood mitigation. Additional measures of physical vulnerability, flood experience, and socio-economic characteristics would enhance the ability to model the variation in flood mitigation activities along the coast. Third, future studies should examine further the negative correlation between mitigation strategies and percentage of floodplain within a local jurisdiction. Presumably there is a threshold where the percentage of floodplain begins to have a negative impact on mitigation activities. This threshold can be flushed out statistically in future work. Fourth, future research should supplement quantitative analyses with qualitative case studies. This research approach will not only help to confirm statistical results, but also to provide a much richer contextual understanding of how localities design their flood mitigation programs. Finally, more work needs to be conducted on connecting specific flood mitigation techniques with property damage and loss of life from flooding events. We have touched upon this topic in the previous analyses (see Brody et al. 2007; Zahran et al. 2008), but more detailed work would provide important insights into which specific activities translate into the highest level of protection from the dangers of repetitive floods.

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Appendix A

See Table 5

Table 5 Indicators for mitigation and organizational capacity

Indicator	Mean	St. deviation
Structural mitigation		
Retention	1.23	0.85
Levees	0.20	0.52
Channelization	0.78	0.86
Dams	0.21	0.48
Debris clearing	1.59	0.62
Non-structural mitigation		
Standalone plan	1.08	0.88
Zoning	0.97	0.92
Setbacks	1.08	0.86
Protected areas	0.90	0.83
Land acquisition	0.76	0.76
Education	1.23	0.59
Training	1.15	0.60
Intergovernmental agreements	1.10	0.69
Referendum	0.20	0.53
Computer models	0.96	0.80
Community block grants	0.58	0.65
Construction codes	1.36	0.89
Specific policies	1.40	0.77
Land development codes	1.46	0.82
Organizational capacity		
Commitment	3.71	1.13
Sharing information	3.72	1.05

Table 5 continued

Indicator	Mean	St. deviation
Verbal communication	3.76	0.97
Sharing resources	3.32	1.21
Networks	3.44	1.15
Leadership	3.77	0.97
Financial resources	2.85	1.25
Available staff	3.02	1.11
Data quality	3.33	1.20
Adjustable policies	3.37	1.04
Long range planning	3.26	1.19
Human ecology	3.12	1.29
Hire and retain staff	3.00	1.37

References

Abell RA (1999) Freshwater ecoregions of North America: a conservation assessment. Island Press, Washington

Alexander D (1993) Natural disasters. Chapman & Hall, New York

Berke P, Roenigk D, Kaiser EJ, Burby RJ (1996) Enhancing plan quality: evaluating the role of state planning mandates for natural hazard mitigation. J Environ Plan Manag 39:79–96

Birkland TA, Burby RJ, Conrad D, Cortner H, Michener WK (2003) River ecology and flood hazard mitigation. Nat Hazards Rev 4(1):46–54

Brody SD (2003a) Are we learning to make better plans? A longitudinal analysis of plan quality associated with natural hazards. J Plan Educ Res 23(2):191–201

Brody SD (2003b) Examining the effects of biodiversity on the ability of local plans to manage ecological systems. J Environ Plan Manag 46(6):733–754

Brody SD (2003c) Implementing the principles for ecosystem management through land use planning. Popul Environ 24(6):511–540

Brody SD (2008) Ecosystem planning in Florida: solving regional problems through local decision making. Ashgate Press, Aldershot

Brody SD, Highfield WE (2005) Does planning work? Testing the implementation of local environmental planning in Florida. J Am Plan Assoc 71(2):159–175

Brody SD, Zahran S, Highfield WE, Grover H, Vedlitz A (2007) Identifying the impact of the built environment on flood damage in Texas. Disasters 32(1):1–18

Burby RJ (1998) Cooperating with nature: confronting natural hazards with land-use planning for sustainable communities. National Academies Press, Washington

Burby RJ, French SP (1981) Coping with floods: the land use management paradox. J Am Plan Assoc 47(3):289–300

Burby RJ, May PJ (1998) Intergovernmental environmental planning: addressing the commitment conundrum. J Environ Plan Manage 41(1):95–110

Burby RJ, French SP, Cigler BA, Kaiser EJ, Moreau D (1985) Flood plain land use management: a national assessment. Westview, Boulder

Burby RJ, May PJ, Berke PR, Dalton LC, French SP, Kaiser EJ (1997) Making governments plan: state experiments in managing land use. Johns Hopkins University Press, Baltimore

Burby RJ, Beatley T, Berke PR, Deyle RE, French SP, Godschalk DR, Kaiser EJ, Kartez JD, May PJ, Olshansky R, Paterson RG, Platt RH (1999) Unleashing the power of planning to create disaster-resistant communities. J Am Plan Assoc 65(3):247–258

Chapin T, Connerly C, Higgins H (2007) Growth management in Florida: planning for paradise. Ashgate Press, Aldershot

Correia FN, Fordam M, Saraiva M, Bernardo F (1998) Flood hazard assessment and management: interface with the public. Water Resour Manag 12:209–227

Dalton LC, Burby RJ (1994) Mandates, plans and planners: building local commitment to development management. J Am Plan Assoc 60(4):444–461
Deyel RE, Chapin T, Baker E (2008) The proof of the planning is in the platting: an evaluation of Florida's hurricane exposure mitigation planning mandate. J Am Plan Assoc 74(3):349–370
Deyle RE, Smith RA (1998) Local government compliance with state planning mandates: the effects of state implementation in Florida. J Am Plan Assoc 64(4):457–469
Dillman DA (2000) Mail and internet survey: the tailored design method. Wiley, New York
FEMA (1997) Multi-hazard identification and risk assessment. U.S. Government Printing Office, Washington
Few R (2003) Flooding, vulnerability and coping strategies: local responses to a global threat. Prog Dev Stud 3(1):43–58
Godschalk DR, Brower DJ, Beatley T (1989) Catastrophic coastal storms: hazard mitigation and development management. Duke University Press, Durham
Godschalk DR, Beathley T, Berke P, Brower DJ, Kaiser EJ, Bohl CC, Goebel RM (1999) Natural hazard mitigation: recasting disaster policy and planning. Island Press, Washington
Grindle MS, Hilderbrand ME (1995) Building sustainable capacity in the public sector: what can be done? Public Adm Dev 15:441–463
Handmer J (1996) Policy design and local attributes for flood hazard management. J Conting Crisis Manag 4(4):189–197
Haque E (2000) Risk assessment, emergency preparedness, and response to hazards: the case of the 1997 Red River Valley flood, Canada. Nat Hazards 21:225–245
Hartig JH, Law NL, Epstein D, Fuller K, Letterhos J, Krantzberg G (1995) Capacity building for restoring degraded areas in the Great Lakes. Int J Sustain Dev World 2:1–10
Hartvelt F, Okun DA (1991) Capacity building for water resources management. Water Int 16:176–183
Holling C (1996) Surprise for science, resilience for ecosystems, and incentives for people. Ecol Appl 6(3):733–735
Honadle BW (1981) A capacity-building framework: a search for concept and purpose. Public Adm Rev 43(5):575–580
Innes J (1996) Planning through consensus building: a new view of the comprehensive planning ideal. J Am Plan Assoc 62:460–472
Ivey JL, Loe RC, Kreutzwiser RD (2002) Groundwater management by watershed agencies: an evaluation of the capacity of Ontario's conservation authorities. J Environ Manag 64:311–331
Kartez J, Faupel C (1995) Factors promoting comprehensive local government hazards management. Paper presented at the nineteenth annual conference of the association of state floodplain managers, Portland, Maine
Larson L, Pasencia D (2001) No adverse impact: new direction in floodplain management policy. Nat Hazards Rev 2(4):167–181
Laurian L, Day M, Backhurst M, Berke P, Ericksen N, Crawford J, Dixon J, Chapman S (2004) What drives plan implementation? Plans, planning agencies and developers. J Environ Plan Manag 47(4):555–577
National Flood Insurance Program (2007) Policy & claim statistics for flood insurance. http://www.fema.gov/business/nfip/statistics/pcstat.shtm. Accessed 9 June 2008
Olshansky RB, Kartez JD (1998) Managing land use to build resilience. In: Burby R (ed) Cooperating with nature: confronting natural hazards with land use planning for sustainable communities. Joseph Henry Press, Washington
Platt RH (1999) Disasters and democracy: the politics of extreme natural events. Island Press, Washington
Simonovic SP, Ahmad S (2005) Computer-based model for flood evacuation emergency planning. Nat Hazards 34:25–51
Smith K (1996) Environmental hazards: assessing risk and reducing disaster. Routledge, London
Stein J, Moreno P, Conrad D, Ellis S (2000) Troubled waters: congress, the corps of engineers, and wasteful water projects. Taxpayers for Common Sense and National Wildlife Federation, Washington, DC
Texas State Data Center (2008) Population growth of Texas. http://txsdc.utsa.edu/. Cited 5 Dec 2008
Thampapillai DJ, Musgrave WF (1985) Flood damage and mitigation: a review of structural and non-structural measures and alternative decision frameworks. Water Resour Res 21:411–424
U.S. Army Corps of Engineers (2006) Services for the publics. http://www.usace.army.mil/public.html. Retrieved 13 Jan 2007
Westley F (1995) Governing design: the management of social systems and ecosystems management. In: Gunderson L et al (eds) Barriers and bridges to the renewal of ecosystems and institutions. Columbia University Press, New York
Whipple W (1998) Water resources: a new era for coordination. ASCE Press, Reston, VA
White GF (1936) Notes on flood protection and land use planning. Plan J 3(3):57–61

White GF (1945) Human adjustment to floods: a geographical approach to the flood problem in the United States. Research Paper No. 29. Department of Geography, University of Chicago, Chicago

White GF (1975) Flood hazard in the United States: a research assessment. Institute of Behavioral Sciences. University of Colorado, Boulder

Wondolleck JM, Yaffee SL (2000) Making collaboration work: lessons from innovation in natural resource management. Island Press, Washington

Zahran S, Brody SD, Peacock WG, Vedlitz A, Grover H (2008) Social vulnerability and the natural and built environment: a model of flood casualties in Texas, 1997–2001. Disasters (4). doi:10.1111/j.0361-3666.2008.01054.x