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Assessing the Relationship Between Flood Risk Perceptions and Adaptive Behaviors of Households

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ASSESSING THE RELATIONSHIP BETWEEN FLOOD RISK PERCEPTIONS AND ADAPTIVE BEHAVIORS OF HOUSEHOLDS

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ABSTRACT

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The purpose of this dissertation research is to examine the multiple relationships that explain household adaptive behaviors to flooding, and if risk perceptions play a mediating role in these relationships. Given the shift in transferring risks from public flood risk governance structures to households, there is a renewed interest in promoting private adaptive behavior amongst households that are vulnerable to flood impacts. Currently, the literature purports that flood risk perceptions rarely account for the variance explained in statistical models that examine household adaptive behaviors. This study analyzed an integrated conceptual framework that explored the mediating role of risk perceptions. The population for this quantitative study is individual households in Portsmouth, Virginia. The integrated conceptual framework considers the assumptions of initial and extended Protection Motivation Theory frameworks. The conceptual framework was analyzed using mediation analysis and the potential outcomes framework to test the hypothesized direct and indirect causal effects of flood risk perceptions and household adaptive behaviors. Findings from this study suggest that flood risk perceptions mediate the relationship between several risk factors on household adaptive behavior (direct experience, indirect experience, knowledge of flooding, locus of responsibility, and race). Based on the results, causality can be inferred that a change in the specified risk factors leads to a change in flood risk perceptions, and a change in flood risk perceptions leads to a change in household adaptive behaviors.

This dissertation is dedicated to my family.

To my mother, Tonya Cowling-Council, who is the epitome of strength, wisdom, and courage. Without you, I wouldn't have been able to get this far.

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1. INTRODUCTION

> "The risks associated with environmental hazards typically depends not only on physical conditions and events but also on human actions, conditions (vulnerability factors), decisions and culture...The seriousness of the consequences of any disaster will depend also on how many people choose, or feel they have no choice but, to live and work in areas at higher risk…(International Council for Science, 2008, p. 14)"

The relationship between what we know about risk perceptions and the degree to which they influence behavioral responses has been a growing area of interest across many disciplines. In the context of natural hazards, various studies have sought to examine this relationship with wildfires, earthquakes, and volcanoes. Flood risk perceptions have been studied to examine their effects on individual and household mitigation behaviors (Brewer, Weinstein, Cuite, & Herrington, 2004; Slovic, Fischhoff, & Lichtenstein, 1986). The general assumption is that the higher a person's risk perception level, the more likely that person is to are to engage in risk reduction behaviors. However, this assumption does not always hold in flooding contexts. More recently, flood risk perceptions have been found to have little to no relationship in explaining household adaptive measures (Bubeck, Botzen, Suu, & Aerts, 2012). This conflicting empirical evidence raises the question, what is the role of flood risk perceptions in explaining the adaptive household behaviors?

Flooding is one of the United States' most common natural hazards. The National Oceanic and Atmospheric Administration (2017) reported that in 2017, there were an estimated 306 billion dollars related to weather and natural hazard damage. Flooding events are increasing in frequency and intensity in coastal communities. It is expected that climate change and sea level rise (SLR) will exacerbate flooding, which increases the vulnerability and potential impacts of those who reside near coastal seaboards (Church & White, 2006, 2011; McBean & Henstra, 2003; Nicholls & Cazenave, 2010; Solomon et al., 2007; Vitousek et al., 2017). These impacts include flooding events that damage homes, individual and community assets, and loss of a region's coastal wetlands (Nicholls, Hoozemans, & Marchand, 1999). Given the severity to disrupt and diminish the quality of life of individuals and communities, environmental hazards are increasingly becoming salient issues for the government (Prater & Lindell, 2000; Terpstra & Lindell, 2013). While the government has taken the lead in providing infrastructure to mitigate the impacts associated with flood events, current and future flood events will exceed the design capacity of traditional public infrastructure (Botzen, Aerts, & van den Bergh, 2009b; Bubeck, Botzen, & Aerts, 2012; Egli, 2002).

Flood management approaches to reduce the impacts associated with flooding have been through structural measures, nonstructural measures, and policy instruments. Traditional flood management approaches focused on large-scale engineering of flood defense structures. Flood defenses are specific strategies that aim to decrease the likelihood and/or the magnitude of flooding by keeping water away from people (e.g., infrastructural works that aim to resist water, such as dikes, dams, barriers, embankments and weirs, upstream retention, or the provision of more space for the water outside of protected areas) (Hegger et al., 2014). In more recent decades, there has been a paradigm shift in flood risk management as the impacts of flooding will exceed the design capacity of traditional structural infrastructure (Botzen et al., 2009b; Bubeck, Botzen, & Aerts, 2012; Egli, 2002), warranting the renewed attention on private mitigation strategies in the natural hazards and disaster field (Godschalk, 2003; Kreibich, Christenberger, & Schwarze, 2011; Terpstra & Gutteling, 2008). This shift is also reflective of the risk management complexities where government agencies are fiscally stressed and severely limited with financial resources to reduce the risks associated with flooding. This means individuals and households will need to take more responsibility in reducing their exposure to flood risks, primarily through adaptation. Adaptation, as an approach to flood management, is defined as the ongoing adjustment to natural, engineered, or human systems in response to actual or expected changes to the climate (Sayers, Goulby, Simm, Meadowcroft, & Hall, 2002). To build their adaptive capacities to flooding, households may elect to adopt a variety of measures that may include participating in government planning activities, elevating their home, or purchasing flood insurance.

Statement of the Problem

At the household level, there has been a lack of interest in investing in non-structural and structural adaptive measures. Non-structural measures such as purchasing flood insurance is a common mitigation tactic to manage and reduce risks (Botzen et al., 2009b; Nations, 2010; Warner et al., 2009). Handmer and Smith (1989) found that some residents with heightened risk perceptions were reluctant to purchase voluntary flood insurance, even when it was affordable. This finding has been found in similar studies (Kellens, Terpstra, & De Maeyer, 2013; Slovic, Fischhoff, & Lichtenstein, 1982; Zaalberg, Midden, Meijnders, & McCalley, 2009), and contradicts the standard assumption that heightened risk perceptions lead to increased mitigation behaviors, as found by Reynaud, Aubert, and Nguyen (2013). Structural measures such as elevating one's home and policy instruments such as participation in government planning have also garnered interest (Jacobs, 2018; Meyer, Priest, & Kuhlicke, 2012; Simonovic, 2002). However, these studies provide mixed results on the role of risk perceptions in explaining adaptive behaviors. The current evidence on the linkages between flood risk perceptions and adaptive behavior is far from consistent (Adger, Hughes, Folke, Carpenter, & Rockström, 2005; Lo, 2013; Wachinger, Renn, Begg, & Kuhlicke, 2013).

While the empirical data show that flood risk receptions rarely account for the variance that explains households' adaptive behavior, there are methodological limitations of previous studies. Where many studies have used single-equation multivariate techniques (e.g., correlation, multiple regression, logistic regression) to directly connect risk perception to household behavior, household behavior may not be a direct function of risk perception. As hinted by various studies that have analyzed various mental-models in the natural hazards field, risk perception may act as a mediating, or intervening, variable between various risk factors and adaptive behaviors of households. This study addresses this methodological limitation by analyzing an integrated conceptual framework that will examine multiple relationships where risk perceptions act as a mediating variable.

Research Question

The study seeks to answer, "Is there a mediating role of flood risk perceptions in explaining adaptive behaviors of households?" In answering this question, the analysis will focus on several key factors that are identified by the Psychometric Paradigm and Protection Motivation Theory that include: risk factors that influence flood risk perception, factors that influence adaptive behaviors, and appropriate analysis techniques that will test beyond a single-equation model.

Purpose of the Study

This study is situated in the broader domain of flood risk management and responds to a growing call for a more systematic approach to understanding societal behavior in response to the changing environment. Flood risk management has become a function of political, administrative, and social systems. Inherently, governments have been faced with the salient issues of climate change and sea level rise and the need to provide strategies to reduce flood risk for vulnerable communities. To promote adaptive behavior in response to current and future flood impacts, practitioners and scholars will benefit from understanding how the cognitive factors attenuate or heighten adaptive behaviors of households (Schanze, 2006). This study is also situated in the emerging field of behavioral public policy. Behavioral public policy is a behavioral science to government that incorporates the principles of behavioral economics and social psychology to understand how the public engages with public policies (Sanders, Sniders, & Hallsworth, 2018; Jonge, Zeelenber, & Verlegh, 2018). This field promotes using an interdisciplinary approach to understand the complex phenomena of human behavior and public policies.

The goal of this study is to analyze the relationship between various risk factors, risk perceptions, and adaptive behavior of households. Two meta-analyses of the health care literature revealed evidence of the role of risk perceptions. Bubeck et al. (2012) found that adaptive flood behaviors are rarely influenced by risk perceptions in statistical analyses. Instead, other contextual and personal variables better explain the relationship, whereas risk perceptions may mediate these relationships. Wachinger et al. (2013) conclude that in the context of natural hazards, a flood risk perception paradox exists that further complicates how to distinguish the motivating factors that can explain a household's protective behaviors. Wachinger et al. (2013) suggest that when attempting to explain the role of risk perceptions and adaptive behaviors, higher levels of risk perceptions may not lead to adaptive behaviors based on three reasons: 1) individuals understand the risk but choose to accept it so that they can live close to a body of water, 2) individuals understand the risk but do not realize any agency for their actions; the responsibility is transferred to someone else, and 3) individuals understand the risk but have little resources to affect the situation. If the role of risk perceptions on adaptive behavior is not made clear, there are several implications for both risk governance and researchers.

First, floodplain and emergency managers utilize the knowledge of how individuals and households assess risks as a means to create and design risk management policies and risk communications strategies. Without proper clarification on the measures needed to assess risks, risk governance structures may fail at providing adequate resources for reducing risks within communities. This may lead to an increase in households that adopt egalitarian, hierarchical, or fatalistic views that often ignore or fail to engage in risk-reducing behavior (Birkholz, Muro, Jeffrey, & Smith, 2014). Research suggests that individuals that are more aware of the risks associated with flooding are more likely to participate in participatory exercises related to disaster preparedness, government planning, and risk reduction behaviors. For example, if people are involved in designing and testing emergency plans, they have a better idea of what the authorities can provide and what each resident can do to improve protection and crisis management. To optimize a flood risk management system, models used to evaluate risk must target effects and side-effects to ensure that the consequences of certain decisions are understood (Schanze, 2006).

Second, researchers who engage in flood risk perceptions studies may reconsider the theoretical and methodological approaches that may better explain household adaptive behaviors. The lack of empirically supported research in examining flood risk perceptions as a means to explain household adaptive behavior challenges the research community to reexamine or create theoretical constructs that may better explain the connection between the two. Without this clarification, models that are used to explain these connections will continue to inadequately explain the factors that influence the adaptive behaviors of households.

Theoretical Considerations

The motivational hypothesis derived from psychology suggests that perceptions of high risk lead to increased coping behaviors (Rogers, 1975; Weinstein, Rothman, & Nicolich, 1998). However, this is not supported on theoretical or empirical grounds in flood contexts (Bubeck et al., 2012; Wachinger et al., 2013). Recent findings reveal that cognitive processes (risk perceptions) used by individuals to evaluate flood risks rarely explain household behavior. Instead, other personal, contextual, and geographical factors may better explain behavior.

To promote private adaptive behaviors, we may better understand the relationship between flood risk perceptions and adaptive behaviors by evaluating the conceptual model used in this study. The conceptual framework used in this study is rooted in the core theoretical assumptions of the original Protection Motivation Theory (PMT) framework (Rogers, 1975) and an extended version of PMT as applied in flooding contexts (Bubeck, Botzen, & Aerts, 2012). The modification to the conceptual framework places risk perceptions in the middle of the extended PMT framework, where risk perceptions are examined as a mediating variable.

PMT posits that individuals protect themselves against risks through four evaluative processes: perceived severity, perceived vulnerability, response efficacy, and self-efficacy (Rogers, 1975). An individual's response to risk is assumed to be a multiplicative function of the factors mentors. These factors are commonly referred to as risk perceptions as they all reflect different dimensions of risk (e.g., probability, magnitude, consequence). When assessing the relationship between risk perception and adaptive behavior, the correlations values are often relatively weak (0.01 – 0.3), r-squared values explain very little variance (.01 – .07), or nonsignificant. Bubeck et al. (2012) suggest that other factors may better explain a household's coping behavior, expanding the initial framework of Rogers (1975). In flooding contexts, risk perceptions along with other risk assessment factors such as knowledge of flooding and proximity to a large body of water are found to explain why households adapt to flooding (Bubeck, Botzen, & Aerts, 2012). Based on an extant review of the factors that influence adaptive behavior, Bubeck et al. (2012) argue that the original assumption that risk perceptions are positively associated with and explain household response is not supported in flooding contexts.

Drawing from an extensive review of the literature, the conceptual framework used in this study examines the mediating role of flood risk perceptions in explaining household adaptive behaviors. To address the inconsistent role of flood risk perceptions, the integrated conceptual framework examines the possible chain between various risk assessment variables that act as external contingencies, flood risk perceptions, and household adaptive behaviors.

While risk perceptions are used as a standard measure in explaining adaptive behaviors, not all risks are evaluated equally. Various factors may directly influence if a household decides to engage in an adaptive behavior, without consideration of a household's perceptions of flood risks. Therefore, household adaptive behavior may be a direct function of other risk factors; risk factors may influence if a household engages in adaptive behavior via their risk perceptions.

Little attention has been given to the mediating role of risk perception in household adaptive behavior. Building on the anecdotal evidence that revealed the relationship between hazard experience and hazard adjustment was mediated by risk perception (Ho, Shaw, Lin, & Chiu, 2008; Lindell & Hwang, 2008; Lindell & Prater, 2000; Martin, Martin, & Kent, 2009), flood risk perceptions are expected to mediate the relationship between various risk factors and household adaptive behaviors in the integrated conceptual framework.

Significance and Relevance of Study

Practical

Flood risk management has become an inherent function of government (Petak, 1985). Public administrators such as floodplain managers have a direct influence on the creation and implementation of risk management policies that include planning, mitigation, response, and recovery phases. These administrators often work in collaboration with other local government departments such as emergency management, city planning, and engineering. To achieve better flood risk governance, governance structures must continuously evaluate approaches that effectively distribute risks among individuals, communities, and society. The distribution of flood-risk responsibility will require reshaping perceptions and motivations. This is not to say that flood managers have absolute power in achieving this goal. Instead, floodplain managers may consider more innovative approaches to engage communities that will shape perceptions and motivations to engage in adaptive behaviors.

Given that the subjective evaluations of risk often conflict with scientific assessments of risk (Loewenstein, Weber, Hsee, & Welch, 2001), household risk perceptions provide critical information to government departments (e.g., floodplain managers, emergency managers, city planners) that are responsible for flood management. Understanding household flood risk perceptions may provide information about households' willingness to take precautionary measures, and support for the government's risk reduction strategies (Botzen, Aerts, & Van Den Bergh, 2009a; Kellens, Zaalberg, Neutens, Vanneuville, & De Maeyer, 2011; Peacock, Brody, & Highfield, 2005). For example, individuals and households' knowledge of risk associated with flooding is promoted as a prerequisite to achieving effective risk communication (Keller, Siegrist, & Gutscher, 2006). Floodplain managers' increased knowledge and understanding of the factors that influence household behavior may yield improvement of a city's participation in

Community Rating System (CRS), a program administered by FEMA to reduce the costs of flood impacts. Increased participation in the CRS may improve the overall access and affordability of private household adaptive behaviors (e.g., flood insurance) to reduce vulnerability in coastal communities. If flood risk perceptions explain adaptive household behaviors, then flood managers can leverage this knowledge to strategize and craft policies that better address households that are motivated by different factors (Bubeck et al., 2012; Kuban, 1996).

With the renewed focus on flood risks being transferred from the government to individuals, floodplain managers along with other government employees that participate in a flood management system must be aware of the factors that may change or influence adaptive behavior.

Research

Currently, theories that have been used to identify the factors that explain household adaptive behaviors in the natural hazards and disaster literature are far from consistent (Bubeck et al., 2012; Wachinger et al., 2013) . The utility of various models used to explain household adaptive behavior is still in a state of infancy. Little research exists that examines the relationship between flood risk perceptions and household adaptive behavior. This study builds on previous research by attempting to explain household behavior beyond a simple, single-equation model. Instead, this model examines the nuanced role of flood risk perceptions that provides a more comprehensive and realistic assessment of household risk evaluation. This study is exploratory and will add the knowledge of how we understand the role of flood risk perception in explaining household behavior.

This research may also be extended to other policy domains where risk perceptions may play a role in understanding how individuals behave in response to perceived threats or hazards. The contributions of this study may provide a novel approach to understanding how public perceptions of risks may provide useful insights into healthcare delivery, law enforcement, or other policy areas.

2. LITERATURE REVIEW

The literature on the relationship between risk perceptions and behavior is extensive and reflects complex and inconsistent findings. The survey of the literature in this study first helps the reader to understand the concepts of risks and hazards as they relate to flooding and coastal vulnerability. Next, risk perceptions are operationalized and discussed, giving a historical background of the psychometric paradigm to risk perception research, an approach developed in the field of psychology. Subsequent research that builds on the psychometric approach to risk perception is discussed and summarized to reflect the various factors that influence risk perceptions that include personal characteristics, experience, and proximity. In the context of flood risk perceptions, the most common variables are identified and discussed that influence flood risk perceptions. Lastly, the literature review concludes with a brief overview of how this study is situated in the broader domain of flood risk management. As risk analysis underpins a dimension of risk assessment, research on risk perceptions continues to evolve as our understanding of how individuals perceive risks and the degree to which they affect their behavior is an evolving area of interest. Households may elect to adopt a portfolio of structural and non-structural adaptive behaviors to adjust to the environmental changes that include climate change and sea level rise.

Risks, Hazards, and Coastal Vulnerability

Risks

The term “risk” takes on many definitions throughout the literature. The terms risks and hazards are often used interchangeably, referring to some potential negative individual or societal impact. Social scientists have made significant progress in shifting the paradigm of how we understand risks and hazards to be a result of solely a biophysical condition to include economic and social conditions (Montz & Tobin, 2012). This section will not exhaustively review the literature on the definitions of risks and, but instead summarize and provide a general overview of the terms as defined throughout the natural hazards literature. A list of definitions is provided in Table 1.

Table 1. Definitions of Risk and Hazard

Author(s)	Risk Definition	Hazard Definition
Lowrance (1976)	"a measure of the probability and severity of adverse effects."	
Hunsaker et al. (1990)		a pollutant or activity and its disruptive influence on the ecosystem
Morgan, Henrion, and Small (1992)	"Risk involves an 'exposure to a chance injury or loss'"	
UNDHA (1992)	Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability."	
Adams (1995)	"a compound measure combining the probability and magnitude of an adverse effect"	
Smith (1996)	Probability x loss (probability of a specific hazard occurrence)	potential threat
Stenchion (1997)	"Risk might be defined simply as the probability of occurrence of an undesired event [but might] be better described as the probability of a hazard contributing to a potential disaster…importantly, it involves consideration of vulnerability to the hazard."	
International Panel on Climate Change (2001)	Function of probability and magnitude of different impacts	

Author(s)	Risk Definition	Hazard Definition
Downing et al. (2001)	Expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period.	a threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period and area.
Jones and Boer (2003)	Probability x consequence	an event with the potential to cause harm (e.g., tropical cyclones, droughts, floods, or conditions leading to an outbreak of disease-causing organisms)
Brooks (2003)		"physical manifestations of climatic variability or change, such as droughts, floods, storms, episodes of heavy rainfall, long-term changes in the mean values of climatic variables, potential future shifts in climatic regimes.."
Straub (2005)	the expected damage (the consequence for the system) per reference time.	
Islam and Ryan (2015)	"a measure of the probability of damage to life, property, and the environment that could occur if manifests itself, including the anticipated severity of consequences to people"	"a natural or manmade threat that may result in disaster occurring in a populated, commercial, or industrial area"

Given the list provided above, several dimensions of risk are noted throughout the definitions. First, the definitions generally refer to risk with some aspect of *probability*. For example, Lowrance (1976) refers to risk as some a measure of probability and its adverse effects. It is not clear of the probability of a hazard occurring he is referring to. Given the ambiguity of definitions, probability may refer to the occurrence of an event or the probability of the severity of an event, given its occurrence. It is not clear which aspect of probability is given. However, both aspects of probability are accepted through the literature. Second, there is also an element of *consequence* related to risk. Consequences are inferred as some negative impact of an occurrence, often resulting in injury or loss. Third, the *magnitude* of risk is often considered by researchers. The magnitude is referred to as the size or severity of an event. For example, the severity of an accident resulting from riding a bicycle without a helmet may be smaller than jumping out of an airplane. Third, the concept of loss is associated with risks. Loss may refer to property, human or animal lives, opportunities, or jobs.

The multidimensional nature of how the term risk is defined is reflective of the varied usage of the term. Risks are operationalized based on the context of an established parameter, often an event. An assessment of the probability, magnitude, and consequences of a given event is generally considered when identifying risks. Therefore, risk is generally accepted as a product of probability x consequence, where the outcome is some negative impact resulting in a loss. For purposes of this study, risk will be defined as "the potential negative impacts associated with an uncertain outcome of an event."

Flooding as a Hazard

Alexander (2002) created a distinction between the various types of hazards to include natural, technological, and social. *Natural hazards* are typically characterized as naturally occurring phenomena that are caused by rapid or onset events. These events are often geological, meteorological, oceanographic, hydrological, or biological with little to no warning. For example, earthquakes are a result of a sudden release of energy in the earth's crust that creates seismic waves, a natural occurrence in the earth's geological makeup. One of the most devastating earthquakes recorded in U.S. history occurred in Northridge, California in 1995. The record 6.7 earthquake magnitude resulted in approximately 57 deaths and estimated property damage between 13 to 50 billion dollars.

Technological hazards are events that are caused by humans, also known as "man-made hazards" that range from transportation and manufacturing, or the use of hazardous substances such as explosives, pesticides, or even debris from space (Islam & Ryan, 2015). One of the most prominent examples in recent history is the British Petroleum (BP) oil spill in the Gulf of Mexico in 2010. Although the event might have taken place inadvertently, the estimated 185 billion gallons contamination threatened marine life, seafood safety, water, and air quality, the coastal economy along with the mental and physical well-being of communities that live near the border the Gulf of Mexico (Gill, Picou, & Ritchie, 2012). *Social hazards* are known broadly as social interruptions that range from terrorist incidents to crowd incidents. These incidents are scattered throughout history and are often a result of individuals or groups that are dissatisfied with government institutions or provoked by political strife.

As defined by the Federal Emergency Management Agency (1997), flooding is the accumulation of water within a body of water and the overflow of excess water onto adjacent floodplain lands. According to FEMA, most floods fall into one of three major categories:

- *Riverine flooding*: This is flooding that occurs along a channel. *Channels* are defined as features (e.g., river, stream, creeks) that carry water through and out of a watershed. When downstream channels receive more rain than usual, or a channel is blocked by a jam or debris, the resultant excess water flows adjacent to the floodplain. This is also referred to as *overbank flooding*.

- *Coastal flooding*: This type of flooding occurs in coastal areas when storm surge results from coastal storms such as hurricanes. According to the Intergovernmental Panel on Climate Change, sea level rise from climate change could be a significant factor for coastal flooding in the next 100 years as it may cause inundation of low-lying areas. Also, climate change would increase the frequency and intensity of hurricanes, and as a result, storm surge would become more frequent
- *Shallow flooding*: This flooding occurs in flat areas where water cannot drain away easily, mainly due to lack of channels. In areas where there are no defined channels, floodwaters drain out at a uniform depth over a sizable known area. This usually occurs during extended periods of rainfall, as the ground cannot absorb all of the rainwaters.

While more severe storms such as hurricanes and nor'easters yield torrential volumes of rain that cause major flooding, nuisance flooding is a type of flooding that is less severe in impact but still causes inconveniences. In contrast to more extreme flooding, *nuisance flooding* (NF) is rarely destructive but is capable of causing substantial socio-economic impacts, business interruption, and public inconveniences such as road closures (Gornitz, Couch, & Hartig, 2001; Jacobs, Cattaneo, Sweet, & Mansfield, 2018; Moftakhari et al., 2015). These are areas where frequent water depth is measured between > 3 cm and < 10 cm, regardless of the source (Moftakhari, AghaKouchak, Sanders, Allaire, & Matthew, 2018). For example, high tide may cause city streets to flood. This means that flooding can also occur without rainfall. These minor yet frequent events are often overlooked. When aggregated over time, NF may have similar cumulative economic and social impacts as major or extreme events.

The most common flood events are climate related, especially from rainfall. Nott (2006) asserts that "normal" flooding is not to be considered a natural hazard unless there is some threat to human life or property. Major flooding events are often characterized as hazards and are associated with severe related weather such as hurricanes, nor'easters, and tsunamis. Within the past decade, the U.S. has felt the effects of these events yielding devastating disruptions to communities across the country. Physical damage to property makes up the largest of tangible losses in floods. A standard indicator of the most significant hazard events is drawn from the economic impacts, an estimated accumulation of property loss. Table 2 provides a summary of the estimated damages in the U.S. from 2007-2017.

Table 2. Yearly Estimated Flood Damages from 2007-2017 Flooding in The United States

Year	Number of Flood Events	Estimated Impact
2008	4	$56.2
2010	2	$4.7
2011	4	$24
2012	2	$75.3
2013	2	$2.8
2014	1	$1.1
2015	2	$4.9
2016	5	$27.4
2017	5	$273.6

Note: Data Sources (NOAA, 2017). No data were available for years 2007 and 2009. Estimated impacts are presented in billions (USD).

The most common and costliest of natural hazards in the United States is flooding (NOAA, 2017). Floods are presented as hazards due to their ability to diminish or reduce the quality of life for individuals and societies at large. The impacts associated with flooding include extensive damage to infrastructures such as power plants and roads, disruption of economic activities, the loss of human and nonhuman life, or the loss of property. Physical damage to property makes up the largest of tangible losses in floods. While all damage cannot be avoided, individuals may behave or adopt a portfolio of behaviors to reduce their risks of property damage or loss associated with flooding.

Damage by flood hazards often depends on the vulnerability of exposed elements (Schanze, 2006). Vulnerability is referred to as the likelihood that an individual or group will be exposed to and adversely affected by a hazard (Cutter, 1993). There are three types of vulnerability, as identified in the natural hazards literature. First, *social vulnerability* refers to the susceptibility of social groups or society at large to potential losses the loss of life, health impacts, stress, and loss of cultural heritage (Cutter, Boruff, & Shirley, 2003). Second, *economic vulnerability* refers to exposure to direct and indirect financial losses by damage to property assets. Third, *ecological vulnerability* refers to exposure to the anthropogenic pollution of soils, waters, and other ecological systems. To be clear, there are no widely agreed upon definitions of these types of vulnerability. However, this study incorporates these specific definitions as they capture the broadest dimensions across the literature.

Coastal vulnerability refers to the exposure of coastal zones to environmental hazards (Green & McFadden, 2007). Coastal communities are amongst the most vulnerable regions to the effects of flooding due to the effects of climate change and sea level rise (Kleinosky, Yarnal, & Fisher, 2007; Nicholls & Cazenave, 2010; Yin, Schlesinger, & Stouffer, 2009). The

International Panel on Climate Change (IPCC), an intergovernmental body of the United Nations that provides the world with an objective view of climate change, defines climate change as any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2013). The impact of the melting ice glaciers as a result of global climate change is likely to raise the sea level by 60 centimeters by 2100 (Martinich et al., 2013). For example, in the United States (U.S.), a 60 cm rise in global (eustatic) sea level by the end of this century would result in a relative SLR of 70 cm at New York City, 88 cm at Hampton Roads, Virginia, and 107 cm at Galveston, Texas, without considering of the impacts of rain or wind associated with storms (Karl et al., 2009). Climate change threatens the livelihood of coastal communities due to their exposure and proximity to water and the effects of sea level rise. This means that climate change will exacerbate future flood events making them more frequent and intense (Smirnov et al., 2018), yielding more substantial impacts.

Flood Risk Perceptions

Risk perceptions are often influenced by a variety of factors, including cultural views, attitudes, scientific information, and worldviews (Dunlap, Van Liere, Mertig, & Jones, 2000). Groundbreaking research on risk perception began in the 1940s by Gilbert White. His research on human adjustments to flooding provided a foundation for the work on risk assessment in multihazard environments (White, 1945). In this study, he found that an individual's previous experience with a flood could explain a person's behavior when the person was under threat.

Risk perceptions are defined as subjective judgments about the probability that a threat will affect an individual (Slovic, 2000). They have been used as a measure to explain the behavior of households in response to natural hazards. The term denotes the process of managing information and signals about uncertain events (Slovic, 1987; Wachinger et al., 2010). It is assumed that flood risk perceptions can provide useful insights into the development of flood risk management (Bubeck et al., 2012). This information is often derived from personal experience, indirect experience, various alerts and signals, and other contextual and situational factors. Risk perceptions are claimed to be a motivating factor to avoid, adapt, or ignore risks (Rogers, 1975; Leventhal, 1970; Lindell & Hwang, 2003). Through the use of the conventional psychometric paradigm, risk perceptions have been captured and examined to help explain how individuals and households cope with perceived threats. In the context of flooding, the studies that have focused on flood risk perceptions attempt to identify the variables that influence households to invest in private, structural, and nonstructural adaptive methods.

Subsequent research on risk perceptions gained traction in the 1960s. Technological and social advances in post-industrial countries, such as the U.S., were becoming more susceptible to the damages associated with natural hazards. During this time, Cook and White (1963) found that the U.S. government spent more than seven billion dollars between the 1930s and 1960s on public infrastructure such (e.g., dams and levees) to mitigate the flood losses of individuals throughout the country. They concluded that the building of public infrastructure might have contributed to the false sense of security of residents to reject individual responsibility in investing in private mitigation measures.

With the advancement of technology, Starr (1969) found a systematic relationship between the acceptance of technological risks and the perception of costs and benefits from those technologies. Types of risks included in this study are traveling by car, travel by commercial aviation, use of firearms, use of nuclear technology, and smoking. The data measured an individual's time exposed to each type of risk per hour, and the number of fatalities associated with each risk in a calendar year. The article concluded that society seemed to accept risks that were associated with perceived benefits. People were willing to accept more significant risks if they were voluntary risks as opposed to involuntary. For example, the public seemed to be willing to accept the risks of skiing and death 1000 times more likely than from an involuntary risk such as eating food preservatives and death. In subsequent decades, risk perception research evolved into more psychological and cognitive experiments that assessed how people evaluate risks. This evolution led to the development of several approaches to risk perception studies that are discussed below.

Psychometric Paradigm

The psychometric paradigm was introduced in the fields of psychology and decision sciences in an attempt to assess risk perceptions and attitudes through quantitative measures (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic et al., 1982, 1986). This approach assumes that risk perceptions and attitudes can be quantified and analyzed to examine their interrelationships with multivariate analysis techniques. Psychometric models assume that risks can be evaluated objectively where mean values are used to compare differences across groups or associations between relationships. These models are often referred to as "cognitive maps." These variables in psychometric models are often cognitive (knowledge-based) and affective (emotion-based) factors that influence the perception of specific properties of the risk in question (Wachinger et al., 2010). Although many of these characteristics are often qualitative, participants of these studies are asked to express their perceptions on rating scales about the various characteristics of the risk in question.

Studies that use the psychometric paradigm are often interested in how laypeople, or the general public, understand risks. This is because there is often a disconnect between how experts and laypeople understand risks. Whereas experts on topics of flooding, climate change, and sea level rise have more discipline-specific knowledge regarding the biophysical changes of the environment, laypeople often derive their understandings of risks based on four levels of context: heuristics of information processing, cognitive-affective factors, social-political institutions, and cultural background (Renn, 2008).

In the earlier studies of risk perception in, Fischhoff et al. (1978) found nine dimensions/characteristics that influence how individuals perceive technological and commonplace risks: 1) where the risk was involuntary; 2) the immediacy of the effect; 3) personal knowledge of the risk ; 4) scientific knowledge of the risk; 5) whether the risk had the potential of being chronic or catastrophic; 6) where the risk was commonplace of dreaded; 7) the perceived severity of consequences of the risk in question; 8) the amount of control an individual had of their exposure to the risk; 9) the novelty of the risk. Dread and novelty explained most of the variance when respondents were asked to rate the risk of several mundane activities (e.g., the use of contraceptives, smoking, and riding bicycles). Slovic, Fischhoff, and Lichtenstein (1980) found two factors that shaped risk perceptions, dread risk, and unknown risk. Using both bivariate correlations followed with principal component analysis, the characteristics within each factor were highly correlated and the respective factors were named. The rating scales for “dread risk” were characterized with questions about their perceived lack of control, dread potential, and fatal consequences of the risk in question. The rating scales for “unknown risks” consisted of questions about the perceived newness, perceived scientific knowledge, and the delay of effects.

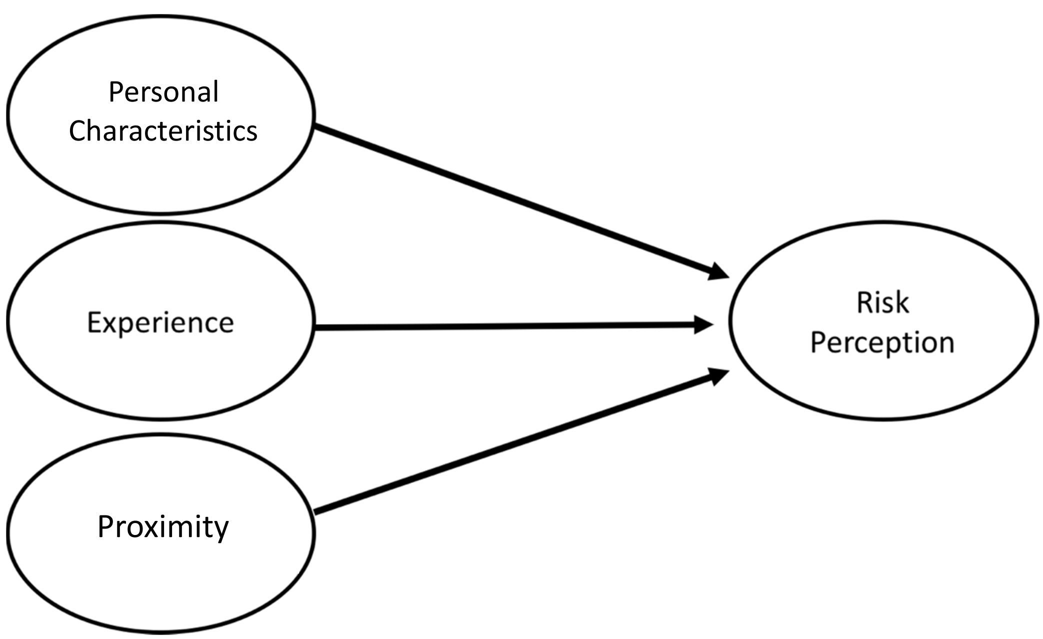
These results were replicated by Slovic and his colleagues in later research adding to the empirical work on risk perceptions (Slovic et al., 1982, 1986).

Factors that Influence Risk Perception

Risk perceptions are unique to individuals and are primarily constructed by information and signals. This information or signals are influenced by the knowledge, personal characteristics, past experience, and environmental conditions (Rohrmann, 1994).

The literature on factors that influence flood risk perceptions extends beyond the context of single flood events that are produced by rain but also include perceptions of climate change and sea level. This is because flooding in many areas is partially influenced by climate change and sea level rise (Poff, 2002). Climate change and sea level rise have been a focus in the recent literature on natural hazards and disasters (Church et al., 2013; Nicholls & Cazenave, 2010). These topics have become salient issues for government and flood risk management structures that are located in or near coastal zones that are vulnerable to flooding that seek to promote appropriate interventions to mitigate and reduce the risks associated with the biophysical changes in the environment. The interest in the psychological determinants of flood risk perception has grown primarily due to flood research being dominated by a technological world view. Whereas previous research on risk perceptions have focused on the factors that influence technological risks (e.g., individual's ranking types of risks, individual's acceptance of risk), flood risk perception studies have begun to uncover the nuanced mental pathways of persuasion that better reflect the mental processes that occur within individuals (Sjöberg, 2000). In the most recent decades, social and socio-economic aspects of flood risk perceptions have garnered more attention in flood risk research as land use has intensified, thus increasing the exposure of human and nonhuman life to the changing environment (Messner & Meyer, 2006). The variables and factors mentioned across flood risk perception studies are discussed below. A schematic view of these factors is represented in Figure 1.

Figure 1. Factors that Influence Risk Perception



Personal Characteristics

Individual's knowledge of flooding, climate change, and sea level rise varies across populations such as differences in culture, geographies, and gender (Leiserowitz, 2006; McCright, 2010; Sundblad, Biel, & Gärling, 2009). Personal characteristics analyzed throughout studies have generally focused on gender, age, race and ethnicity, and income. This is because flood risk perceptions are often associated with social systems.

Women have been shown to have more concern over the risks associated with natural hazards such as flooding and the effects of climate change (Brody, Kang, & Bernhardt, 2010; Leiserowitz, 2006) while men have been shown to be less concerned with natural hazards and climate change (Flynn, Slovic, & Mertz, 1994). Other studies have found that women, in general, are more likely to view the world as risky and seek to take measures to reduce the impacts of environmental hazards through voluntary action. On the contrary, men are more likely to invest in low cost, nonstructural efforts such as supporting government policies (O'Connor, 1999). This is not to say that women are more concerned, and men are less concerned. A plausible explanation for the heightened risk perceptions for women is that women are thought to be socialized into the role of a nurturer while men take on more of a role as an economic provider (Mohai, 1997). Therefore, women tend to perceive the effects of climate change differently for men, raising their concerns over natural hazards and climate change (Brody et al., 2008). This hypothesis was further supported in a study by Ho et al. (2008). This study revealed that there were statistically significant differences between men and women risk perceptions. Gender was a significant predictor in explaining the change in risk perceptions of residents in Taiwan who experienced frequent flood events and landslides. Ho et al. (2008) concluded that women tended to view the recurring hazardous events as riskier due to their lower socioeconomic status and were more sensitive to the possibility of resource loss (e.g., money, property). This study recommended that risk communication efforts should target women given that men were less likely to invest in private mitigation measures. One study was found that indicated that men to have more heightened risk perceptions than women (Botzen et al., 2009b).

The perceptions of various races and ethnicities have also garnered interest in the risk perception literature. However, few studies exist that examine the relationship between ethnicity or race and risk perception. Ethnic minorities tend to have higher perceptions of natural hazards than non-White ethnicities. African Americans and Mexican Americans tend to have high perceptions of the seriousness of natural hazards. In a study by Blanchard-Boem (1997), the researchers reported that blacks were more likely to report a concern of an earthquake damaging their home than non-black ethnicities. Turner et al. (1980) studied the risk perceptions variance among racial groups concerning earthquakes in California. Differences were discovered amongst racial groups where blacks were more fatalistic about their concern of earthquakes while Mexican Americans and whites were equal about their fatalistic feelings. Contrary to other studies, in a study of floods in South Carolina, there were no significant differences found among racial groups (Ives & Furuseth, 1983; Turner et al., 1980).

The relationship between race and ethnicity and risk perception may be attributed to the historical racial tensions of underrepresented and marginalized communities. Ethnic minorities have often been exposed to environmental hazards at higher rates than other ethnicities (Bullard & Lewis, 1996; Bullard & Wright, 2009; Cutter, 1995; Maantay & Maroko, 2009; Mohai, Pellow, & Roberts, 2009). This is due to the intentional placement of ethnic minorities (e.g., African Americans, Mexican-Americans) on highly toxic lands/brownfields. The history of ethnic minorities being placed in high exposure regions to toxins and natural hazards has created a disproportionate experience in the response and recovery of ethnic minorities when experiencing natural hazards. Blacks have had much more difficult times recovering to the impacts associated with flooding, climate change, and sea level rise. The most convincing evidence of this claim is during the 2005 Hurricane Katrina in New Orleans, Louisiana. Those who represented the black population felt as if the anticipated floods were more severe due to their inability to access and afford transportation to relocate from the storm (Baade, Baumann, & Matheson, 2007; Mohai et al., 2009). Subsequent research revealed that black participants were more concerned about the impacts of flooding than non-black participants (Elder et al., 2007; Elliott & Pais, 2006). Ethnic minorities are perceived to have a higher concern of flooding, climate change, and sea level due to their likelihoods of being placed in high exposure areas and their reduced likelihood of having the response to and recovery from flood impacts.

At the intersection of race and gender, the "white male effect" has been consistently found amongst risk perception studies. This term is referred as the result of the socialization of white identifying males; white males perceive the risks associated with natural hazards as less severe (Finucane, Slovic, Mertz, Flynn, & Satterfield, 2000; Marshall, 2004). Due to the social privilege associated with males (the social privilege derived from white male patriarchy to have advantages in navigating and receiving benefits from social, political, and economic systems), white males have been shown to be more sympathetic to hierarchical, individualistic, and anti-egalitarian values (Finucane et al., 2000; Kahan, Braman, Gastil, Slovic, & Mertz, 2007).

Few studies have found a correlation between an individual's income and their perception of the risk in question. Early questions were raised concerning the utility of socio-demographic variables in explaining hazard perceptions. American geographer Gilbert Gilbert F. White (1974) argued that the variance in hazard perception is rarely explained by socio-economic attributes, including income. In one study by Flynn et al. (1994), they found that individuals with lower incomes reported heightened levels of risk perceptions. The authors hypothesized that poorer people might view their socioeconomic status as a hindrance in their ability to cope with environmental hazards. Therefore, they may hold little power in controlling their lives. This hypothesis was partially supported by Grothmann and Reusswig (2006). In their study, income was not found to be correlated with the perceived probability of experiencing a future flood. However, income was positively correlated with coping appraisal, the process by which individuals evaluate their ability to cope with a risk. This suggests that there is a relationship between the level of an individual's income and their ability to feel confident in coping with a risk. Subsequent research by Lindell and Hwang (2008) revealed that income was negatively correlated with perceived risk. In this study, participants from single-family dwellings in Harris Country, Texas were randomly surveyed on their perceived risks and hazard adjustments across three types of hazards (floods, hurricanes, and chemical releases). Using a perception scale for each hazard as a dependent variable, income was significantly correlated to perceived risks across all hazards. In a recent study of Portsmouth, Virginia, there was a statistically significant difference in the perception of flooding between low-to-moderate income households and higher income households (D. Council, Covi, Yusuf, Behr, & Brown, 2018). Although risk perception studies within the natural hazards continue to collect participant income in their studies, the evidence for this relationship is inconclusive.

Experience

Personal experience affects how individuals learn about and perceive risks. Arguably one of the most predictable variables in risk perception research, past experience, contends to be the most influential construct in psychometric studies. Previous hazard experience generally is found to increase risk perceptions (Burningham, Fielding, & Thrush, 2008; Keller et al., 2006; Knocke & Kolivras, 2007; Lara, Saurí, Ribas, & Pavón, 2010; Miceli, Sotgiu, & Settanni, 2008; Terpstra, 2011; Terpstra & Gutteling, 2008). An individual's experience with a hazard can be defined by the recency and frequency of casualties and damage experienced by the individual by him/herself, by members of their family, immediate social network (Lindell & Hwang, 2008).

People who live in flood-plain areas are more familiar with flooding, but may have mixed opinions about future flood events (Baan & Klijn, 2004; Siegrist & Gutscher, 2008; Takao et al., 2004; Zaalberg et al., 2009). When comparing flood victims to non-victims in Switzerland, victims tended to have stronger fear of towards flooding and perceived the consequences of future flooding as more severe compared to non-victims (Takao et al., 2004). The notion that there is a relationship between a person's direct experience with a risk in question and the development of their risk perception is well established in the broader psychological literature (Chawla, 1999; Fazio & Zanna, 1981a; Fazio, Zanna, & Cooper, 1978; Fortner et al., 2000). In a meta-analysis of studies that analyze the role of direct experience, Fazio and Zanna (1981b) reported that direct experience (defined as an interaction with an object) is more likely to report stronger attitudes towards that object that those who have indirect experience (second-hand information about the interaction of an object). Botzen et al. (2009b) have shown that citizens that report experience with previous floods and flood evacuation expressed higher perceptions of the likelihood to experience flooding, but lower perceived consequences. They concluded that although the majority of the participants had experienced previous flooding, many had not experienced damage associated with flooding. Therefore, it can be argued that the effect of experience is not simple and depends on how people interpret their experiences.

Proximity

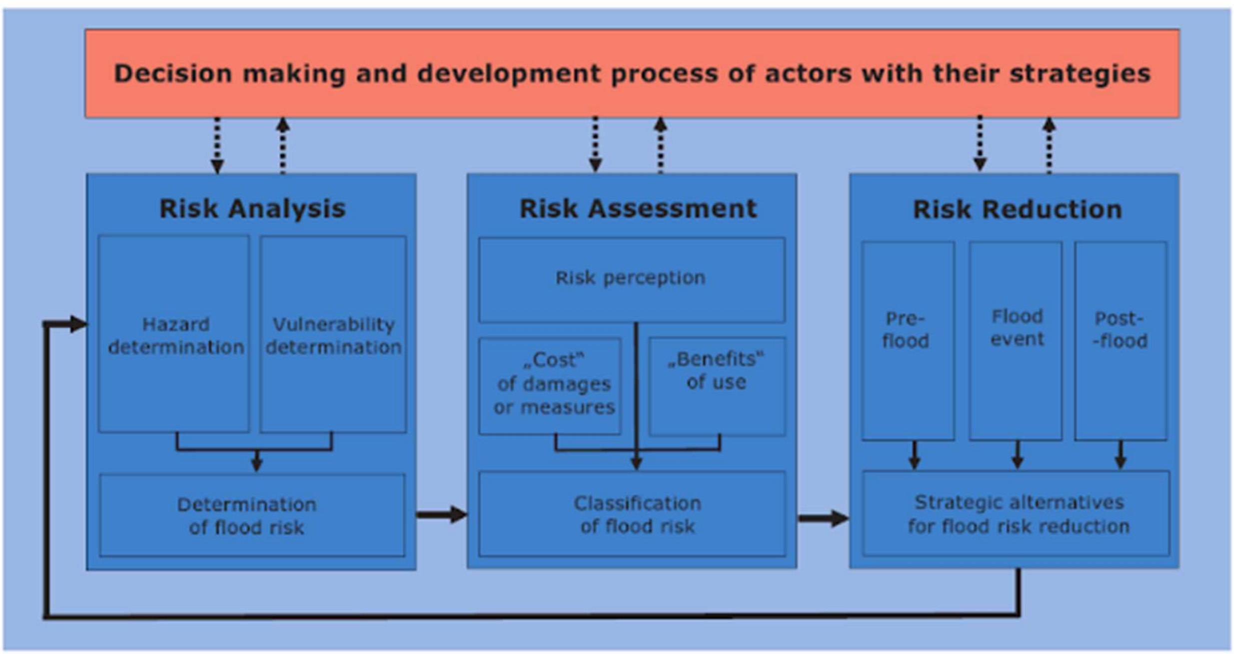
Proximity or distance from a risk plays a role in shaping flood risk perceptions (Maderthaner, Guttmann, Swaton, & Otway, 1978). The physical exposure to environmental hazards, such as a river or low-lying area, are often correlated to flood risk perceptions. For example, Lindell and Hwang (2008) examined the relationship between hazard proximity and risk perception of households in Texas. Their findings revealed that people who reside farther away from large bodies of water (e.g., rivers, coastlines, and other alike) reported less concern over perceived severity and consequences of floods and hurricanes.

One assertion concerns how individuals choose their residency by maximizing space, accessibility, and environmental amenities (Fujita, 1989). This implies that some individuals may accept risks based on the recreational benefits associated with living near access to water. This proposition was also suggested by Wachinger et al. (2013) where individuals choose to accept the risks of living near bodies of water where 1) individuals understand their risks but the recreational benefits outweigh the associated risks (e.g., private boating, fishing), and 2) perceived social benefits (e.g., living in or near wealthy communities to sustain a perceived social status).

Flood Risk Management, Adaptation, and Household Behavior

Schanze (2006, p.6) defines flood risk management as a "holistic and continuous societal analysis, assessment, and reduction of flood risk." Under the guise of flood risk management, there are three components that structure management activities: risk analysis, risk assessment, and risk reduction. Risk perception, the focus of this study, falls under the assessment which is the process of evaluating the psychological-cognitive approaches of how individuals understand risks. See Figure 2. The actors involved in flood risk management vary, but often derive from a combination of representatives to include government (local, state, and federal), politicians, planning authorities, or water authorities. These actors are involved in the decision-making process and development processes, and vary across cultural, political, and administrative systems.

Figure 2. Flood Risk Management System



Source: (Schanze, 2006)

The effects of climate change and sea level rise present challenges to low-lying and coastal communities across the globe with increased flood events (IPCC, 2013). Flood management approaches to reduce the impacts associated with flooding have traditionally been through structural measures (e.g., dikes, levees), nonstructural measures (e.g., forecast warnings), and policy instruments (e.g., land use planning). In the attempt to optimize and complement existing flood risk reduction strategies, there is a renewed interest in building flood management systems by transferring risk from public agencies to individuals (Botzen et al., 2009b). Practitioners that engage in flood risk management realize that the sustainability of long-term flood defense structures will not be adequate to cope with the more frequent and intense flood events (Treby, Clark, & Priest, 2006). This is because the impacts of flooding are expected to exceed the design capacity of many structural measures (Brody et al., 2010; Coulthard & Frostick, 2010). Households have been encouraged by governments and the insurance industry to engage in private adaptive measures to cope with the impacts of flooding. This paradigm shift in flood management emphasizes adaptation as an approach to coping with the rapid changes in the environment.

Adaptation, as an approach in flood management, is defined as the ongoing adjustment to natural, engineered, or human systems in response to actual or expected changes to the climate (Sayers et al., 2002). Because no adaptation strategy other than complete abandonment removes the risk associated with flooding, households may build a portfolio of adaptive behaviors to adjust to the changing environment and reduce the impacts. To better understand how households respond to flooding, risk perceptions have been used as a standard measure in explaining adaptive behaviors.

Adaptive Behaviors

Adaptive behaviors are the actions that households engage in to adjust to the anticipated impacts of flooding, particularly to reduce the impacts that may damage their homes. These behaviors are commonly categorized into two groups: structural measures and nonstructural measures. Adaptive behaviors at the household level are often referred to as "private" measures as they measure that are not provided by public institutions under traditional flood management.

At the household level, structural measures are referred to as the physical structures that are constructed or modified to reduce the impact of flooding on an individual's property. These measures are often perceived as more expensive but are recommended as measures to complement large-scale traditional public defense structures. For example, FEMA (2012) recommends the following as measures for households to understand that are vulnerable to flood events, sea level rise, and climate change:

- Replace exterior and interior home components with more hazard resistant material (e.g., water-resistant floor tiling);
- Retrofit critical structures to be elevated one foot above the 500-year flood plain level (considering wave action if you are near large bodies of water) or the predicted sea level rise level, whichever is higher (e.g., an HVAC unit); and
- Acquiring and demolishing or relocating property structure that is in a high-risk area

Nonstructural measures are referred to as measures that are taken to reduce the impacts associated with flooding to a home without structural modification. These measures are often less expensive. Examples of these measures include:

- Using outreach programs to facilitate technical assistance programs that address measures that citizens can take or facilitate funding for mitigation measures,

- Engaging in public awareness programs (e.g., safety during flood conditions, including the dangers of driving on flooded roads),
- Participating in government planning activities (e.g., land use planning),
- Using weather technologies to forecast conditions to properly plan for weather inconveniences,
- Purchasing flood insurance through the National Flood Insurance Program.

Theoretical Considerations

This study considers the assumptions of Protection Motivation Theory in its original model and its later development in the context of natural hazards. Whereas household adaptive behavior is hypothesized to be a multiplicative function of an individual's cognitive processes, this study considers these theoretical developments to further our understanding of how individuals evaluate risks, but also places context around the methodological limitations of previous studies. To better understand the relationship between flood risk perceptions and adaptive behaviors, theoretical considerations of these value-expectancy models are appropriate for this study.

Protection Motivation Theory

PMT developed from the field of psychology. Ronald Rogers (1975) developed this model as an alternative to Leventhal's (1970) dual process model of understanding stimuli that invoke motivational behavior. PMT initially aimed to understand how verbal persuasion (fear appeals) can lead to an individual's change in attitude, which manifests into a change in behavior. Leventhal (1970) defined fear appeals as messages that describe the unfavorable consequences that might occur from failure to adopt the communicator's recommendations. For example, a fear appeal could be a pamphlet that highlights how a lack of exercise leads to obesity. The basic concepts of PMT are discussed below.

Fear Appeals. Fear appeals have a rich history in the field of psychology based on two influential models. First, *the fear-drive model* postulates that fear acts as a driving force to motivate behavior (Janis & Feshbach, 1953). The second model, *the fear as a motivational intervening variable model,* postulates that organisms are motivated to respond from a stimulus-response condition, where fear is anecdotal to initiate the stimulation (Dollard, Miller, Doob, Mowrer, & Sears, 1939). In the early work of Hovland, Janis, and Kelley (1953), three stimulus variables were assumed to influence a fear appeal 1) the size or magnitude of an adverse of noxious event, 2) the likelihood an event will occur if no action is taken, and 3) the efficacy of a recommended coping response to reduce or alleviate an adverse event. In Roger's (1975) initial conceptualization of PMT, he attempted to provide clarity on the cognitive mediational effects in explaining protective behaviors.

Rogers' use of the stimuli factors mentioned above is rooted in distinct dimensions of risk perception. The psychology literature has already established an active role in the relationship between risk perception and motivation. Building on the work of Leventhal (1970) who used fear appeals to change attitudes and behaviors and Postman (1953) who discusses linkages between perception, motivation, and behavior, Rogers revised Leventhal's theory, distinctly defining the dual process of how individuals assess risks through threat appraisal and coping appraisal.

Building on Leventhal's model, Rogers noted that there is a difference between a person's feelings of concern of a threat (the severity of the risk) versus a person's belief of the likelihood that the threat will directly affect them (the personal consequences of the risk). He also makes a clear distinction between the efficacies of a recommended behavior (its usefulness in alleviating a problem) versus the ability of the recommended behavior to assist them directly in mitigating the threat. This is to say; risk perceptions are clearly defined as an assessment of one's vulnerability and an assessment of an individual's capacity to reduce their vulnerability. The clear distinction between the variables provides for a more straightforward operationalization of each variable. The distinction also provides guidance direction on the measurement of each variable so that the construct validity remains strong as researchers design appropriate data collection techniques and tools for analysis.

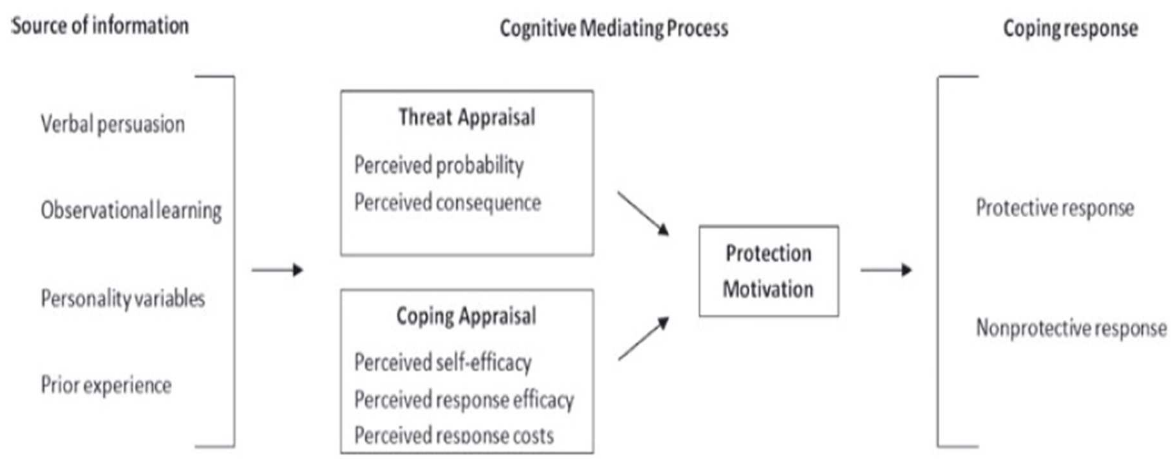
Sources of Information. Rogers' original PMT model helps us to understand the stimuli that initiate risk appraisal. These are considered the model inputs. He proposed that the information people received about risks aroused fear stimuli. According to Rogers (1975), these sources of information were assumed to come from verbal persuasion, observational learning, personality, and prior experience.

Threat Appraisal. The model stimuli produce appraisal processes to respond to fear. The model helps us to now understand 1) how individuals perceive risk, and 2) how those risk perceptions lead to a behavioral outcome. PMT was presented to be an improvement over its predecessors by specifying the cognitive variables that mediate the process from information synthesis to behavioral response. It suggests that people are motivated to protect themselves based on two cognitive processes, threat appraisal, and coping appraisal. The purpose of the model initially was to persuade people to follow a communicator's recommendation. Therefore, changes in intentions indicated the effectiveness of persuasion. Within the threat appraisal process, individuals assess risk based on a) the magnitude of the risk, *perceived severity*, and, b) the likelihood the risk will affect them, *perceived vulnerability*. These are commonly referred to as "risk perceptions."

Coping Appraisal. Within the coping appraisal process, individuals a) assess if a recommendation will be beneficial to them, *response-efficacy*, b) the individual's belief in their ability to adopt a recommendation, *self-efficacy,* and, c) an individual's assessment of how costly it is to implement a recommended behavior, *response costs*. In the theory's infancy, only three cognitive variables were considered. The theory was expanded again by Maddux and Rogers (1983) to include self-efficacy and response costs. This was due to the researchers realizing that an effective coping response was not enough for the subject to adopt that response. Instead, the subject must also believe that they are capable of performing the behavior (Maddux & Rogers, 1983; Tunner, Day, & Crask, 1989).

Protection Motivation/Behavior. In the original model, *protection motivation* or *protective behavior* is hypothesized to be a multiplicative function of the mediational process between both the threat appraisal and coping appraisal. Protective motivation is defined as an individual's intention to adopt a recommended behavior, whereas protective behavior is an action that has already been implemented. The assumption is that protection behavior is a positive linear function of risk perceptions. This means individuals that have higher levels of threat and coping appraisal are more likely to take an action that will reduce their risks. For example, for individuals that smoke, their increased levels of risk perceptions of probability and consequences of smoking (threat appraisal) along with high levels of self-efficacy, response efficacy, and response costs (coping appraisal) lead to an increased willingness to implement protective behavior (reduce, stop, or avoid smoking). Later, the model was revised to include sources of information that could invoke protective behaviors that include personality variables, and prior experience with risk. A schematic overview of the model is presented in Fig. 3.

Figure 3 – Roger's (1975) Original Protection Motivation Theory Framework



Predictability and Methodological Approaches. The literature has commonly assessed the relationship between the cognitive factors of PMT and protective behavior through single-equation multivariate analysis, typically using ordinary least squares or logistic regression. Research design types include correlational design and experimental design where the unit of analysis is individuals. Correlational designs have examined the associations between PMT constructs with intention, behavior, or both. Experimental designs included control groups with educational interventions or manipulating PMT variables. For example, in a study on cancer, one group watched a video on cancer awareness while the control group watched a video on another topic (Seyde, Taal, & Wiegman, 1990). The study found that the type of information received influences protective motivation. In an experimental manipulation study, participants may be given different materials. For example, in a study on exercising, participants were split into two groups where one group received information on low response efficacy and a second group received information on higher response on higher response efficacy (Stanley & Maddux, 1986). The information stressed the importance of exercising in overall health and attractiveness, a coping appraisal variable in the PMT model.

The threat and coping appraisal factors are postulated as antecedents to protection intention or protection behaviors. In a multivariate statistical equation, the cognitive factors are treated as independent variables and the protection intention or behavior is treated as the dependent variable. In an OLS regression model that predicts risk behavior, a regression equation would be similar to the example below:

$$y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \varepsilon$$

Where, y = protection motivation/behavior

X_1=perceived severity

X_2=perceived vulnerability

X_3=response efficacy

X_4=self-efficacy

X_5=response costs

ε =error term

In determining the strength of each variable, common statistical indicators such as Pearson correlations, effect sizes, beta coefficients, and r-squared values have been the most consistent indicators when determining their strength and influence. Through the conventional use of the psychometric paradigm, data collected using PMT constructs were conducted primarily by questionnaires using Likert scale responses. See Table 3 for examples of how each variable has been operationalized.

Table 3. Examples of PMT Constructs

Variable		**Example**		**Response Scale**
Perceived Severity	-	AIDS is a serious disease	-	strongly agree to strongly disagree
Perceived Vulnerability	-	Considering all of the factors that may contribute to AIDS, including your own past and present behavior, what would you say are your chances of getting AIDS?	-	I am almost certain I will to I am almost certain I will not
Response Efficacy	-	Using condoms would help me to reduce the chance of getting AIDS	-	strongly agree to strongly disagree
Self-Efficacy	-	I feel confident that I can use condoms	-	strongly agree to strongly disagree
Response Costs	-	The costs associated with condoms are reasonable for me to purchase	-	strongly agree to strongly disagree
Protective Behavior	-	I use condoms when I have sex	-	yes or no

Subsequent research employing PMT gained traction within the healthcare literature. Studies ranging from smoking cessation, binge drinking, and other threat studies have sought to understand how each of the variables whether used together or in isolation contribute to how people make decisions to protect their health or wellbeing (Floyd, Prentice-Dunn, & Rogers, 2000; Norman, Boer, & Seydel, 2005; Rippetoe & Rogers, 1987). In a study of breast cancer awareness, Rippetoe and Rogers (1987) disseminated information to women and examined the effects of the information per the components of PMT. The analysis revealed that response efficacy (the belief that breast self-examination can detect early signs of cancer), self-efficacy (the belief in their ability to implement self-examinations, and severity (the belief that breast cancer is serious) positively correlated with the intention to practice self-examinations.

Several meta-analyses of the PMT framework have concluded that the model is useful in explaining the cognitive variables that influence protection motivation and protective behavior. Milne, Sheeran, and Orbell (2000) conducted a quantitative review of PMT components (threat appraisal and coping appraisal) to determine if the core theoretical assumptions hold true in health-related contexts. After a review of 27 health-related articles comprised of a total of 7,942 participants, the associations between threat and coping appraisal and health-related intentions and behaviors support the assumptions of PMT. The review includes both correlational and experimental research designs.

As suspected, the coping appraisal factor was found to have more explanatory power. These findings were consistent in a more extensive meta-analysis, indicating that the PMT model variables were statistically associated with protective intention or protective behavior (Floyd et al., 2000). In addition to Milne et al.'s (2000) study, the authors included the variable response costs. They also contend that although the model variables were significant, the positive pooled correlation effects were low to moderate (r = .20) for threat appraisal variables and the coping appraisal variables ($r = .26$). In sum, the explanatory power of the variables is low, which may hint at other processes that are a part of the risk appraisal process.

PMT began to be applied to other contexts to explain behavioral responses to threats. For example, in Tsai's (2016) study, the researcher aimed to understand which variables could explain the motivation of internet users and their security intentions. Their findings indicated that coping appraisal variables significantly ($p <. 01$) explained security intentions ($r^2 = .18$), in which the authors suggested have implications for governments and individuals to improve online safety. In another study by Glendo and Walker (2013), PMT was applied in the context of understanding speeding intentions. The authors noted that PMT had never been applied to understand the variables that were key to explaining speeding intention, and its application suggested that severity ($p < .05$) and vulnerability ($p <. 05$) were the most influential variables. Implications of this study provided support for their ongoing development of anti-speeding messages to reduce crash risks and injury severity.

Limitations. A critical review of studies that employ PMT finds that cognitive factors are significantly related to protective behaviors. A limitation that is noted throughout the review is that although the cognitive factors are assumed to serve as a mediator in the risk appraisal process, they are not tested as a mediator through statistical analyses. Research has provided support of the usefulness of these cognitive factors. However, after examining their effects sizes, correlation values, and variance explained, values are typically low to moderate. It is understood that psychometric models rarely account for more than 60% of the variance explained (Slovic et al., 1982, 1986). This is due to the nature of social science research where models rarely take into account all of the human dimensions that explain human behavior. Another reason to explain the low values is the lack of consistent definitions of risk perceptions. Ogden (2003) argues that in her analysis of findings of PMT, in an article by Murgraff, White, and Phillips (1999), they stated that their idiosyncratic findings might be contributed to the wording of the PMT measures (p. 348). The multidisciplinary usage of PMT warrants each discipline to build over time a consensus of appropriate survey instruments that accurately measure the intended variable. This has been a consistent limitation of the PMT framework.

The cognitive heuristic provided by Rogers has rarely applied to multi-equation models to reflect that risk appraisal process. This is to say, information processing from messages and personality variables (inputs to the model) should be measured as antecedents that may better improve model explanations, where risk perceptions mediate the relationship with protective behavior. Few studies consider the pre-decisional processes that may account for other variables that explain risk behavior. The original PMT model provides value in identifying the cognitive factors that are useful in explaining the individual response to risks. However, there exists an empirical gap in understanding the true mediational role of the cognitive factors that warrant further investigation that takes into account the pre-decisional variables that individuals use in their risk appraisal process.

Extended Protection Motivation Theory Framework

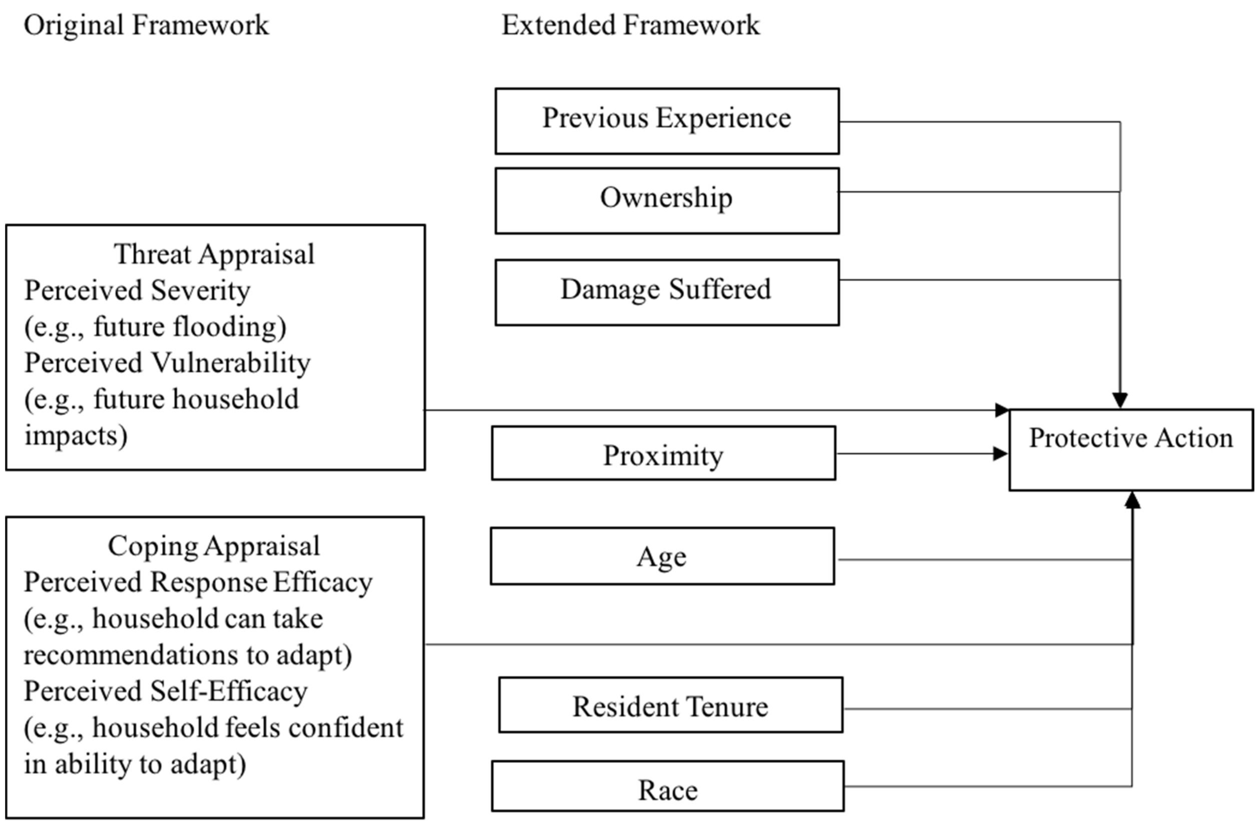
Today, more than four decades since the birth of PMT, its utility has been deemed useful across a variety of disciplines to include natural hazards. The natural hazards literature has focused on the human dimensions to understand how individuals behave in response to weather-related risks such as hurricanes, wildfires, earthquakes, tornadoes, and volcano eruptions (National Research Council, 2006).

PMT has been used as a social cognition model to understand how individuals assess flood risks and their intention to adopt a protective behavior or a behavior that has already been implemented.

The focus on risk perceptions as a measure to gauge risk behavior has dominated the natural hazards literature. Within flooding contexts, few studies have empirically demonstrated an association between risk perceptions and protective behaviors. The common assumption is that heightened risk perceptions lead to an increased likelihood of protective responses. Homeowners that have experienced flood impacts are more aware of flood risks and are more likely to invest in precautionary measures (Bichard & Kazmierczak, 2012; Grothmann & Reusswig, 2006; Miceli et al., 2008; Osberghaus, 2015). However, this assumption does not hold true in flood contexts (Bubeck, Botzen, & Aerts, 2012). Bubeck et al. (2012) suggested that the focus flood risk perceptions as a measure to explain and promote flood mitigation behaviors are not supported on theoretical or empirical grounds. Bubeck et al. (2012) developed an extended framework of Roger's (1975) original PMT model to include other contextual factors that have been found to be correlated with protective behavior in flooding contexts. The extended framework suggests that there is a need to focus on other factors that explain behaviors versus the conventional risk perception approach. A schematic overview of the model is in Figure 4. In an effort to understand the utility of PMT in flooding contexts, 16 peer-reviewed studies were considered in their analysis comprising of over 12,000 participants. The articles were chosen based on the authors' attempt to provide an explanation for the weak relationship between flood risk perceptions and protective actions. Research designs considered for their meta-analysis were all correlational, using regression to examine the independent variables with a dependent variable (flood mitigation behavior) or t-test to examine differences between groups where the unit of analysis is households. Next is a brief overview of the extended framework variables.

Threat Appraisal. Similar to the core assumption of PMT, studies have sought to capture how individuals perceive the magnitude of flooding. Positive correlations were found in only a few studies with flood protective behaviors. Lindell and Hwang (2008) surveyed owner-occupied single-dwelling homes in Harris County Texas and found a small correlation between perceived severity and the adoption of flood insurance (r = .17). The relationship explained 5.5% of the variance in the model. Similar results were found in Thieken et al.'s (2007) study of households in three communities in Germany that experienced slow-onset river flooding and flash flooding. The results indicated that only one group's perception correlated with purchasing flood insurance (r = 0.2, p <.01), while the other two groups were non-significant. The non-significant findings of perceived severity with flood mitigation behaviors were consistent with the other studies surveyed in their analysis that measured this variable.

Figure 3. Extended Protection Motivation Theory Framework



Using a combined measure of perceived severity and perceived vulnerability (perceived risk), Grothmann and Reusswig (2006) find support in explaining its relationship to flood precautionary measures. Cologne, Germany is a city that is susceptible to major and minor flooding. Four logistic regression models were examined that used threat appraisal variables to predict protective responses (informing oneself about self-protection, avoidance of expensive furnishings, purchase of flood protection devices, and structural measures). Threat appraisal was statistically significant in all of the models expect avoidance of expensive furnishing and could explain 3-6% of the models' variance.

Coping Appraisal. The coping appraisal construct across the flood studies captures various dimensions of the original PMT model, response efficacy, self-efficacy, and response costs. These three dimensions are often treated as a single variable throughout the literature. A majority of the studies found statistically significant relationships between coping appraisal variables and protective behaviors (Grothmann & Reusswig, 2006; Kreibich, Seifert, et al., 2011; Siegrist & Gutscher, 2008; Zaalberg et al., 2009). In a study of households in flood-prone areas in the Netherlands, Zaalberg et al. (2009) found that perceived effectiveness was positively related to the intent to adopt a protective behavior ($p < .0001$), self-efficacy was not correlated with protective behavior. Through several structural equation models, the reported beta coefficient values for perceived effectiveness ($\beta = 0.69 - 0.76$) suggesting support of its causal relationship to protection behavior of PMT.

Protective Behaviors. In flooding contexts, protective behaviors are considered actions that households take to reduce the risk of flooding to their home. Throughout the literature, these actions may be called mitigation measures, private investments, precautionary behavior, or preparedness behavior. Essentially, the research on flood risk reduction behaviors will typically measure this variable by asking about specific types of approaches that have been identified for a geographic region to reduce flooding impacts. The most common of these approaches has been a focus on household private mitigation measures such as purchasing flood insurance, along with other approaches such as purchasing sandbags, relocating furniture within a home, relocating major appliances, or elevating one's home. For example, Miceli et al. (2008) surveyed 470 households in Italy on their preparedness with flooding. In their survey questionnaire, they asked if someone in the household did the following protective behaviors: keep a working flashlight and a battery operated radio in a convenient location, keep a readily available list of emergency phone numbers, teach (and/or arranged with) relatives what to do in case of emergency, attend a first-aid course, purchase any kind of insurance against natural disasters, ask someone (local government, Civil Defense) information about what to do in case of emergency, store essential objects in a safe place, store emergency food and water supplies, or make some changes to their home. The results indicated that flood risk perceptions, age, and proximity to water significantly and positively predicted the adoption of a protective behavior.

How Experience with Flooding Affects Adaptive Behaviors. Of the most consistent factors, experience with flooding has shown promise in explaining its relationship with adaptive behaviors. Weinstein (1989) concluded that direct experience with automobile accidents and natural hazards increase one's likelihood of wearing seatbelts or purchasing flood insurance. Other studies have also hinted at the spike in flood insurance purchases after a disaster (Baumann & Sims, 1978; Kunreuther et al., 1978). In Bubeck et al.'s meta-analytic review of the literature, experience with flooding was consistently found to be associated with adopting a risk reduction behavior (Grothmann & Reusswig, 2006; Kreibich, Seifert, et al., 2011; Lindell & Hwang, 2008; Siegrist & Gutscher, 2006, 2008; Thieken et al., 2007). The role of experience is well established within the psychology literature. Studies have consistently found that individuals learn through direct experience, and their experiences yield stronger attitude-behavior consistency (Chawla, 1999; Fazio et al., 1978; Fortner et al., 2000). This is commonly referred to as direct experience and is reflected by the regency and frequency of flood events that affect an individual personally.

Damage to property as a result of flood events is also considered experience with flooding. Takao et al. (2004) found that residents of Japan that had previously experienced damage to flooding were more likely to take extraordinary measures to protect themselves against flooding, although the measures were not stated explicitly.

Geographical Factors. Geographical factors were analyzed through the studies that examined the relationship between flood risk perceptions and protective behaviors. The geographical study areas represent some of the most sensitive and flood threatened areas in the world. Of these studies, Europe was highly represented (three in the Netherlands, four in Germany, two in Switzerland, one in Italy, one in Poland), followed by two in the United States (both in the state of Virginia), and one in Japan. Coastal communities, in particular, are the most vulnerable as they experience the effects of flood events that are a result of environmental changes such as tidal flooding, storm surge, and rainfall. Proximity to a large body of water such as a river, dam, or coastline has been measured used to assess a household's intention to adopt some protective behavior to reduce their risks of flood damages. For example, Miceli et al. (2008) found that households in Italy that were closer to bodies of water were more likely to adopt a protective behavior. This was consistent with the findings of Botzen et al. (2009b). Kriesel and Landry (2004) provided anecdotal evidence to the assumption that the further away a household is from a beach vegetation line or shoreline, the less like the household to participate in the National Flood Insurance Program. The results indicated that a 1% increase in distance from the shoreline decreased the probability of holding flood insurance by 88%. They concluded that although some households have accepted the risks to live near a beach or shoreline, other households may use distance as a protective measure to decrease their probability of being affected by flood events, which was later supported by Wachinger et al. (2013).

Socio-economic Factors. Measures of age, ethnicity, and income have also been found to have marginal effects in promoting protective behaviors. Young adults are less likely to understand the severity of flood-related weather and their potential impacts ($p < .01$) and are assumed to be less likely to engage in protective actions (Knocke & Kolivras, 2007). Blacks and Mexican-Americans were thought to be more fatalistic about natural hazards such as earthquakes (Turner et al., 1980) and more likely to perceive natural hazards to severely damage their homes as high or extremely high (Blanchard-Boehm, 1997). However, Lindell and Perry (2012) find that White participants had a higher correlation to flood insurance ($r = 0.16$).

It is assumed that households with higher levels of income are more likely to invest in protective behaviors because they have more financial resources. Currently, the literature reflects inconsistent findings on the relationship. Income has been found to be significantly and positively related to the adoption of flood insurance (Botzen et al., 2009b; Kriesel & Landry, 2004) with marginal effects, Lindell and Perry (2012) and Zaalberg et al. (2009) observe insignificant correlation values between household income and flood insurance.

Several studies have investigated the differences between homeowners and non-homeowners and their intent to protect themselves against flooding. Small to medium correlations were found ($r = 0.11 – 0.45$) that predicted a household’s intent to engage in protective “devices” such as the installation of water pumps, heating pumps, and window barriers (Grothmann & Reusswig, 2006). This was consistent with homeowners in Germany (Thieken et al., 2007). Two plausible explanations may explain this relationship. One, homeowners are more invested in their properties and view their home as a more extensive liability. Two, homeowners who take out a loan from a federally regulated or insured lender and buy a home in a Special Flood Hazard Area are required to purchase flood insurance (NFIP, 2007). While homeowners are more likely to invest in flood protection measures, renters have a lower demand (Kreibich, Thieken, Petrow, Müller, & Merz, 2005; Thieken et al., 2007).

Initial support for the extended PMT framework was conducted by Poussin, Botzen, and Aerts (2014). Expanding the geographic location PMT studies, over 600 households in three flood-prone regions in France were surveyed to uncover the factors that influence mitigation measures across three models. The models included all of the variables proposed by Bubeck, Botzen, and Aerts (2012). Poussin et al. (2014) used household structural measures, avoidance measures, and emergency preparedness measures as separate composite dependent variables in the three OLS regression models and a household's intentions to implement a measure was used as a binary dependent variable in the logistic regression model. As suspected, the threat appraisal variable had a small positive and significant effect on the intention to implement a mitigation measure ($ß = 0.54$) but nonsignificant for the other three models. Likewise, the coping appraisal self-efficacy was significant and positively related to structural measures ($ß = 0.20$) and avoidance measures ($ß = 0.14$). Response costs was significantly and positively related to structural measures ($ß = 0.13$), avoidance measures ($ß = 0.17$), and emergency preparedness measures ($ß = 0.12$).

The findings also confirm that inconsistent influence of additional variables in the conclusion of Bubeck et al. (2012). Flood experience was significant and positively related to avoidance measures (ß = 0.13) and emergency preparedness (ß = 0.12). Homeownership only correlated with the structural measures model (ß = 0.08). The size of the household was also only correlated in the structural measures model (ß = 0.07). Surprisingly, income was not correlated to any of the models, which may be a result of overrepresentation of the study's sample population. Overall, the models were able to explain between 19-31% of the variance.

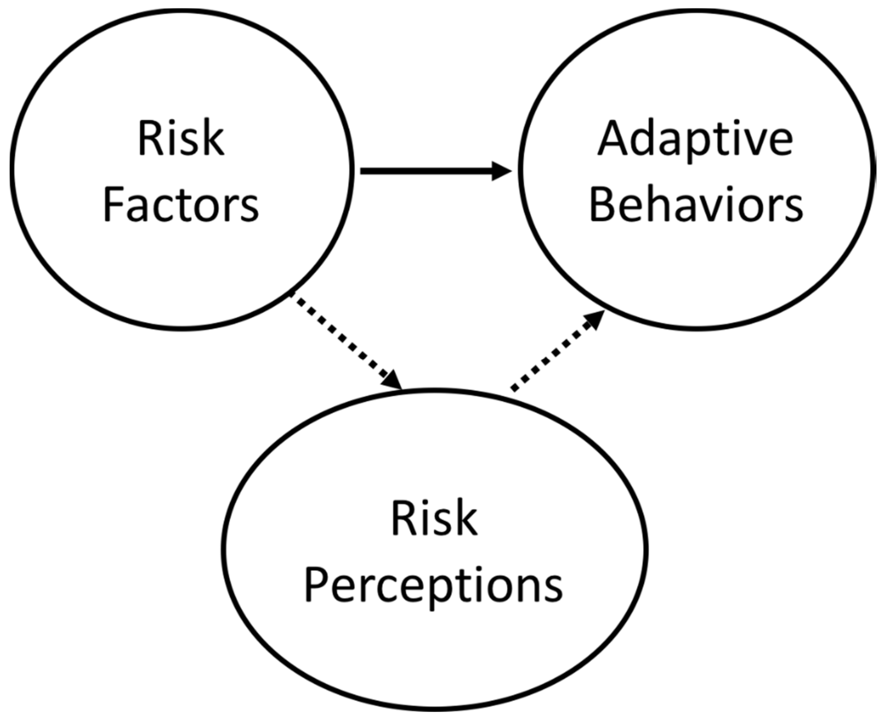
3. CONCEPTUAL FRAMEWORK

Integrated Conceptual Framework

The conceptual framework in this study represents a mental-model, a mental image of the world that contains selected concepts and relationships (Forrester, 1971), or “cognitive map,” that postulates risk perception as a mediating variable in explaining household behavior. This framework is rooted in several core assumptions. First, risk perception is an outcome of various risk factors, as cited in the literature review. Second, household adaptive behavior is an outcome of risk perception. Third, risk perception is also an intermediate outcome of risk factors and affects household behavior based on an inferred causal chain.

As evidenced in the survey of the literature, risk perceptions have been well studied and are found to correlate to both various risk factors and adaptive behavior. This is because risk perceptions act as both a mediating variable and outcome variable. For example, while risk perceptions are derived from various factors (e.g., experience, residency tenure) or predispositions (e.g., socio-demographic characteristics, geographic location), risk perceptions also explain household behavior (e.g., the adoption of various measures). The findings of low to nonsignificant correlation and p values, or the variance explained by flood risk perceptions in explaining household behavior may be attributed to systematic and methodological limitations that are addressed in the conceptual framework. See Figure 5 for a schematic representation of the conceptual framework.

Figure 4. Conceptual Framework



*the dotted line represents the mediating relationship
*the solid line represents a direct relationship

Risk Factors

The conceptual framework posits that adaptive behaviors are a function of risk factors and can be mediated by risk perceptions. The risk factors variables are preconditions to both risk perceptions and adaptive behavior. In this model, risk factors are referred to as an attribute or characteristic that exposes an individual to the impacts of flooding. As identified throughout the literature, these factors are broadly known as: personal characteristics (e.g., age, income, race, homeownership, residency tenure), proximity (e.g., distance from a body of water), and experience (e.g., the recency and frequency of casualties and damage experienced by the individual or immediate social network).

More recently, *locus of responsibility* and *knowledge of risk* have been found to affect how individuals respond to natural hazards. As defined by Martin et al. (2009), locus of responsibility is referred to as an individual's level of acceptance of personal responsibility to protect themselves against a natural hazard. Knowledge is referred to as what individuals believe they know about a risk domain. Martin et al. (2009) surveyed 251 residents in Colorado and Oregon on their knowledge of wildfires, fire experience, self-efficacy, responsibility, risk perception, and risk reduction behaviors due to their vulnerability to recurring wildfires. Locus of responsibility was measured using a composite score by asking the respondents "how responsible should you be for protecting yourself from the impact of wildfire'' and ''how responsible should you be for protecting your property from the impact of wildfire'' anchored by 1 = not at all responsible and 4 = very responsible. Knowledge was measured using a composite score by asking respondents ''how well informed do you consider yourself to be about wildfire and wildfire risks'', ''to what extent do you find information about wildfires to be personally relevant'', and ''how motivated are you to learn more about the connection between wildfire risks and undertaking behaviors to create defensible space.'' Examples of the adaptive behaviors include planting fire-resistant plants around the home, putting fire-resistant undersides to decks and balconies, and getting a local fire department to inspect the home. Both locus of responsibility and knowledge were found to have significant and positive relationships with the adaptation of a risk reduction behavior.

In sum, the integrated conceptual framework refers to risk factors as 1) personal characteristics, 2) proximity, 3) experience, 4) locus of responsibility, and 5) knowledge of flooding.

Flood Risk Perceptions

Flood risk perceptions influence the adoption of adaptive household behaviors. Consistent with the natural hazards literature, flood risk perceptions are referred to as the subjective evaluations regarding the various attributes of flood risks. They are subjective beliefs regarding the magnitude, severity, and consequences associated with flooding, and are influenced by a variety of factors. Risk perceptions can explain how individuals and households choose to adapt to flooding. In a successive chain, various risk factors influence an individual's risk perceptions, and risk perceptions influence adaptive behavior. Therefore, risk perceptions are posited as a mediating variable between risk factors and household adaptive behaviors.

As supported throughout the psychological literature and PMT, risk perceptions represent a cognitive process that humans use to evaluate risks. Cognitive processes appear to mediate the relationship between various attributes and relationships that are specific to the natural hazards literature. For example, in Lindell and Hwang's (2008) study on household responses to three types of hazards (flood, hurricane, and chemical spills), the results indicated that the risk perception measure partially mediated the relationship between hazard experience and hazard adjustment. They conclude that hazard experience influences one's hazard perceptions, which in return causes hazard adjustment adoption. Anecdotal evidence of the role of risk perceptions in explaining households' wildfire risk reduction was conducted by Martin et al. (2009). The study reported that risk perception indirectly mediated a household's wildfire reduction behavior. Similar evidence was found by Lo (2013), where risk perceptions mediated the relationship between perceived social norms and the intention to purchase flood insurance. He contends that social norms which were measured by the level in which individuals thought 1) their family or friends want them to insure, and 2) their level of agreement in which they thought people like them would purchase insurance. Martin et al. (2009) also found initial support of the mediating role of risk perceptions. The results from this study show that there was a partial mediational effect both the relationship between locus of responsibility and risk reduction behaviors, and knowledge and risk reduction behaviors.

In essence, risk factors pass through risk perceptions and lead to an adaptive response. This is because risk perceptions, as a cognitive process, tend to be formed after various risk factors are considered in risk analysis, not before. Based on an individual's position in society, their risk factors lead them to evaluate risks, which then leads them to an adaptive response.

Household Adaptive Behaviors

Household adaptive behaviors are the behaviors that households engage in to adjust to the impacts of flooding. At the household level, these behaviors can be both structural and nonstructural. Structural behaviors are actions that households engage in that alter or modify the structural composition of the makeup of their home. Examples of these behaviors include elevating one's home or installing green infrastructure around the home. Non-structural behaviors are those that involve less work and refer to the actions that households engage in that alter the impact of flooding without altering the structure of their home. Examples include participation in government planning (e.g., land use planning) and emergency preparedness activities or purchasing flood insurance. To maximize flood management efforts, households may adopt a portfolio of adaptive behaviors to adjust to the environment and reduce their vulnerability to flooding.

The claim that the relationship between flood risk perceptions explaining household behavior may be overemphasized (Bubeck, Botzen, Suu, et al., 2012; Wachinger et al., 2013). The low to nonsignificant statistical values used to determine the effect size and variance explained of risk perceptions on household behavior may be attributed to an indirect causal influence. There is reason to believe that risk perceptions pass through various risk factors and affect changes in behavior in response to flooding. Based on the premise that humans are organisms that react to stimuli, humans receive information through the various personal and contextual risk factors as evidenced throughout the literature. Risk perceptions then become a function of these various risk factors. Behavior then becomes a response to risk perception and risk factors (Baron & Kenny, 1986; Maddux & Rogers, 1983). Below is a visual representation of this proposed causal chain:

Risk Factors →Flood Risk Perceptions → Household Adaptive Behavior

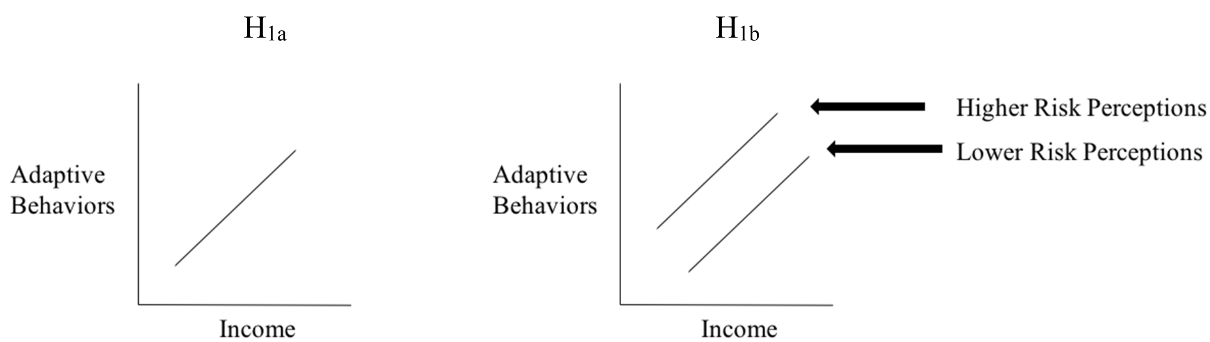
This conceptual model tests a mediated hypothesis of Bubeck et al.'s (2012) extended PMT framework by placing flood risk perceptions in the center of the framework. I argue that the claim that flood risk perceptions are not supported on empirical or theoretical grounds in explaining household protective behaviors warrants further investigation. The conventional single-equation models limit the researcher in explaining complex phenomena such as risk reduction behavior. For example, hazard experience is expected to influence risk perceptions, and risk perceptions are expected to influence a household's risk reduction behaviors. That is to say, each successive variable is hypothesized to mediate the relationship between the variable that precedes it and the variable that follows it. In this example, risk perception mediates the relationship between hazard proximity and a household's protective actions. This suggests that multi-equation models may better disentangle and explain a variety of data generating processes.

This research builds on the research suggestions of Lo (2013) further exploring the role of risk perceptions by ascertaining its influences on the collective and personal attributes of a community. Like many other studies that use PMT as an analytic framework, a majority of the studies reviewed used OLS regression, logistic regression, t-tests, and nonparametric analyses to test the influence of various factors in explaining household behavior. These single-equation models rarely take into account the potential mediating factors that influence this relationship. Given the claim that risk perceptions are not supported on empirical or theoretical grounds, the small or insignificant findings may hint at the true mediational role that Rogers (1973, 1985) postulated in the original PMT framework.

Research Hypotheses

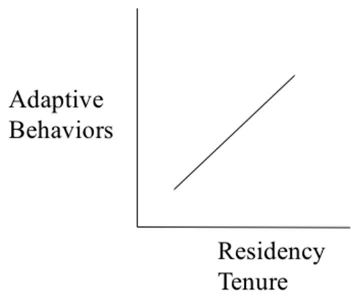
The following hypotheses are based on the review of the literature and the theoretical framework:

- H_{1a} - There is a direct relationship between income and household adaptive behaviors
- H_{1b} - Flood risk perceptions mediate the relationship between income and household adaptive behaviors

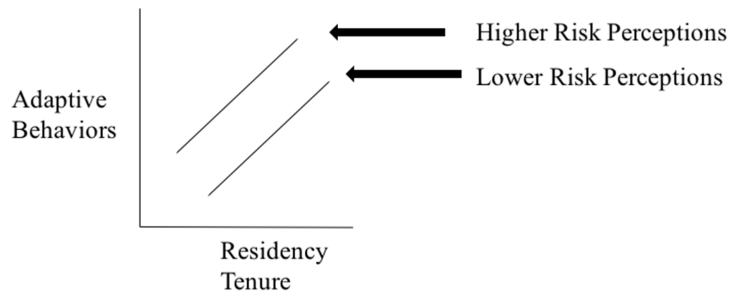


- H_{2a} - There is a direct relationship between residency tenure and household adaptive behaviors
- H_{2b} - Flood risk perceptions mediate the relationship between residency tenure and household adaptive behaviors

H_{2a}

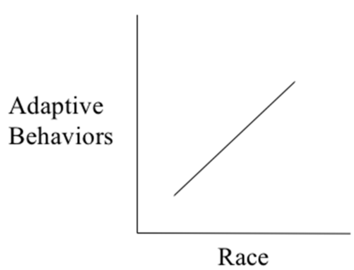


H_{2b}

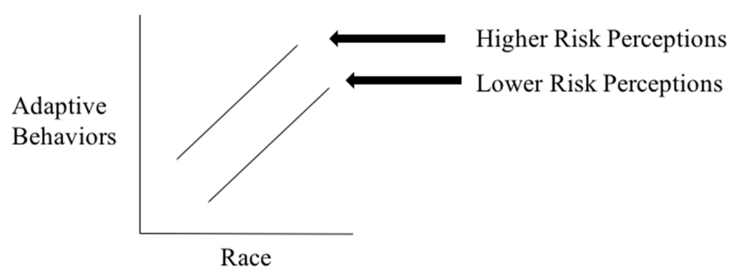


- H_{3a} - There is a direct relationship between race and household adaptive behaviors
- H_{3b} - Flood risk perceptions mediate the relationship between race and household adaptive behaviors

H_{3a}

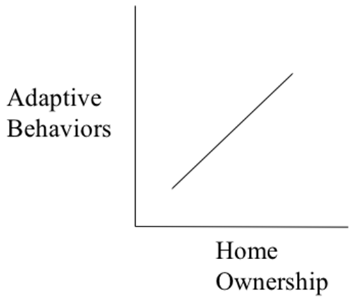


H_{3b}

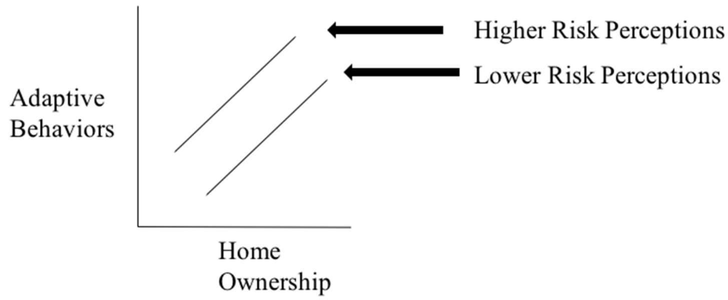


- H_{4a} - There is a direct relationship between experience and household adaptive behaviors
- H_{4b} - Flood risk perceptions mediate the relationship between experience and household adaptive behaviors

H_{4a}

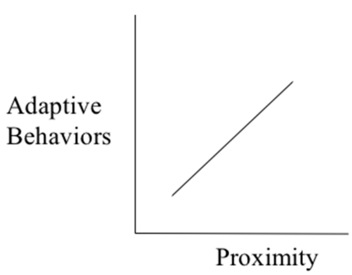


H_{4b}

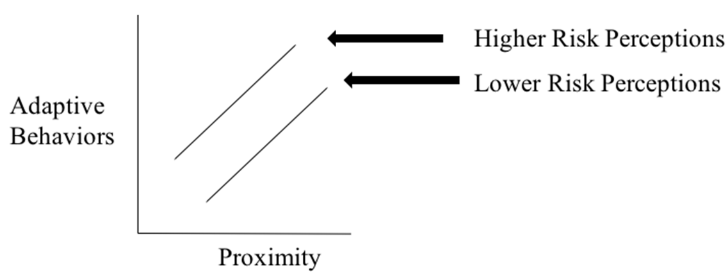


- H_{5a} - There is a direct relationship between proximity and household adaptive behaviors
- H_{5b} - Flood risk perceptions mediate the relationship between proximity and household adaptive behaviors

H_{5a}

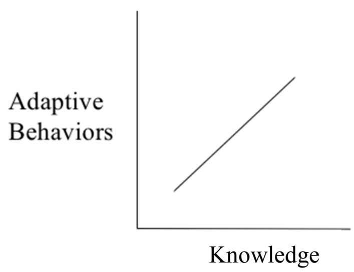


H_{5b}

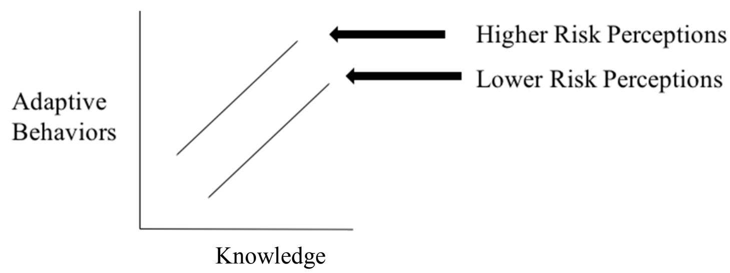


- H_{6a} – There is a direct relationship between a household’s knowledge about flooding and household adaptive behaviors
- H_{6b} - Flood risk perceptions mediate the relationship between a household’s knowledge about flooding and household adaptive behaviors

H_{6a}

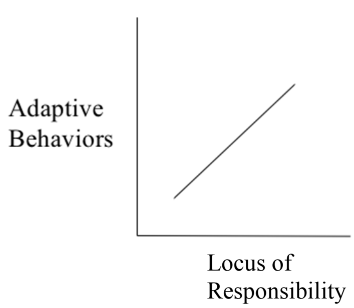


H_{6b}

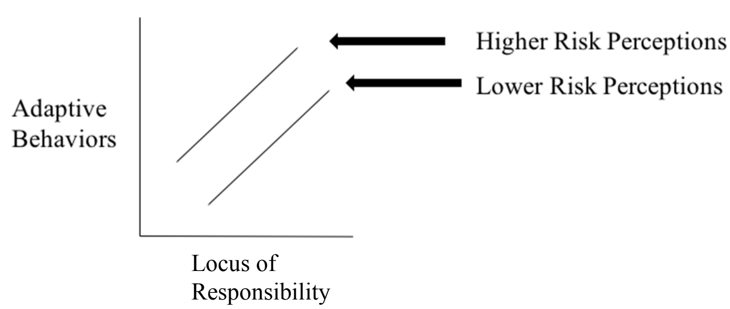


- H_{7a} – There is a direct relationship between a household’s perceived locus of responsibility about flooding and household adaptive behaviors
- H_{7b} - Flood risk perceptions mediate the relationship between a household’s perceived locus of responsibility and household adaptive behaviors

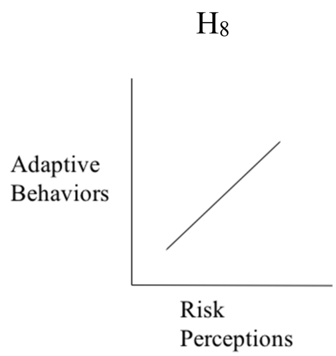
H_{7a}



H_{7b}



- H_8 - There is a direct relationship between flood risk perceptions and household adaptive behaviors



4. METHODOLOGY

Study Design

To answer the research question "Is there a mediating role of flood risk perceptions in explaining adaptive behaviors of households?" this study will employ a quantitative methodology using a cross-sectional data set to examine the multiple relationships in the conceptual framework. To examine the multiple relationships proposed in the conceptual framework, a cross-sectional survey design was found to be appropriate to examine these relationships. Most risk perception researchers have a used cross-sectional self-reporting methodology due to limitations on collecting time series data.

Research Context

Portsmouth, Virginia is a coastal community that is situated in the Hampton Roads region of Virginia. In 2013, the U.S. Census Bureau reported that the city had a population of approximately 95,000, 33 square miles of land, and a median household income of $46,166 (Bureau, 2013). More than 18% of the population live below the federal poverty line. Approximately 40% of the population identifies as White, 55% identify as Black, with the remaining 5% identify as other racial groups. Through geophysical analysis, research has established the region is highly vulnerable to SLR and flooding due to its proximity to the Chesapeake Bay, land inundation, and sea level rise. (Kleinosky et al., 2007). Even further, residents of this area have also been identified as highly vulnerable based on socio-demographic characteristics including rural setting, race, income, and education level (Liu, Behr, & Diaz, 2016; Stafford & Abramowitz, 2017). This presents challenges to this region as vulnerable individuals and communities are less likely to be able to anticipate, cope with, and recover from a hazard. Among the socio-economic challenges of the most vulnerable, additional regional barriers have been identified in addressing regional sea level rise in Hampton Roads which include political leadership, institutional and stakeholder engagement, adaptation decision making, funding for adaptation, and public support for adaptation (Yusuf & St. John III, 2017).

Data from the Life in Hampton Roads Survey (2017) reveals that more than 70% of residents in Hampton Roads are concerned with neighborhood and regional flooding. The Adaptation Response to Recurrent Flooding Report (2015) conducted in Portsmouth (n=1,978) revealed that a majority of the respondents were concerned with flooding and faced significant challenges. Examples of these challenges are high levels of street flooding near their homes, the inability to get in or out of their neighborhoods, and damage suffered as a result of flooding. About 27% of the respondents indicated that they have flood insurance, and about 14% have made changes to their home as a result of flooding. As projections of sea level rise are likely to rise by 60 centimeters, the confounding effects of SLR, climate change and land subsidence may yield an 88-centimeter rise in sea level in Hampton Roads by 2100 (Martinich, Neumann, Ludwig, & Jantarasami, 2013). A significant portion of households in Portsmouth are challenged with making decisions on how to best mitigate and adapt to the changing environment to minimize the associated risks and impacts. The ability of a protective action or coping behavior to adequately protect an individual or community largely depends on several factors such as the duration of an event, characteristics of the hazard, the population affected and response resources in place (Sorensen, Shumpert, & Vogt, 2004).

Within the last 20 years, Portsmouth has felt the impacts of several flood events. For example, in 2003 Portsmouth felt the impacts of the category one Hurricane Isabel where most of the low-lying areas were under water. Although there were less than two inches of recorded rainfall, a combination of rainfall and storm surge yielded substantial impacts such as road closures, stalled motorists, and property damage. The flood losses had an approximate value of over three millions dollars, and over 300 claims were filed by the city (Portsmouth, 2015). In subsequent years, Portsmouth would also experience Hurricane Ernesto in 2005, Hurricane Irene in 2007, Hurricane Sandy in 2015, and Hurricane Matthew in 2016 as reported by the National Weather Service (2017).

In the city's most recent floodplain management update, flooding was identified as the most dangerous and reoccurring natural hazard for the city. This was based on several indicators. First, under the new flood maps, a category three hurricane would have 75% of the city underwater. Second, the projected rise in SLR will result in a loss of 1-3.6 square miles of land. Third, in 2014, the city had over 200 identified repetitive loss properties, ranking them seventh highest city within the state (Portsmouth, 2015).

Data

The data come from the Adaptive Capacity Behavioral and Experiential Data Mapping Project conducted in 2013 in Portsmouth, Virginia (Behr et al., 2015). This telephone survey was conducted by the Social Science Research Center at Old Dominion University in partnership with the Virginia Modeling, Analysis, & Simulation Center. The survey contains 41 questions related to the experiences, perceptions, and adaptive behaviors of households that experience recurring flood events. A list of the survey questions used in this study is listed in Table 6.

Sampling

Through a random stratified sampling process, 1,978 Portsmouth households were interviewed of the total household population of 36,690, accounting for roughly 5.4 percent of all Portsmouth households constituting a margin of error of no more than three percent. The unit of analysis is individual households. The sample drew upon cell phone data and listed landline data. Responses were geocoded to the households' nearest residential cross street. This geocoded data allows the researcher to examine the intensity of responses relative to features such as proximity to coastline and flood zone. Given the focus of this study on risk perceptions and household adaptive behavior, participants that reported that they rented their homes were removed. This was due to the specific nature of this study that focuses on household adaption by homeowners. Three hundred ninety-six observations were removed from the dataset.

Data Analysis

To establish that a mediating variable has a causal effect on an independent and dependent variable, quasi-experimental methods have been the traditional approach to estimate a causal effect. When using observational data, it is difficult to establish causality due to several reasons. First, observational, or secondary data, cannot be manipulated by the researcher and cannot be randomly assigned. Second, there are limitations in the temporal ordering as the data are often collected during one time period. Third, because observational data are not randomized, they cannot control for exposures or factors that may be causing the results (Nichols, 2008). Therefore, linkages between an independent variable, dependent variable, and mediating variable can be speculative. To overcome many of these limitations, several advancements have been made in the mediation literature to test the significance of causal mediation effects and are discussed below.

The data were analyzed in three steps. First, to establish that mediation exists amongst the hypothesized relationship, individual ordinary least squares regression equations were conducted following the Baron and Kenny (1986) procedure, followed by the Sobel (1982) test. Second, the average causal mediation effects and average direct effects were estimated using

–medeff- command in the *–mediation-* program in Stata created by Hicks and Tingley (2012). Third, a sensitivity analysis was conducted using the *–medsens-* command in STATA to investigate the robustness of the results to the violation of the sequential ignorability assumption as suggested by Imai, Keele, and Yamamoto (2010).

Step 1 – Mediation Testing and Analysis

To examine the research question "Is there a mediating role of flood risk perceptions in explaining adaptive behaviors of households?" a series of individual multiple linear regression equations were conducted to assess if risk factors explain household adaptive behaviors via flood risk perceptions. A multiple linear regression assesses the relationship among a set of nominal, ordinal, or interval/ratio predictor variables on an interval/ratio criterion variable.

The traditional method of establishing for mediation comes from Baron and Kenny (1986) using three steps:

i. the independent variable must have a statistically significant variation on the mediating variable (Path *A* to *M* is significant)
ii. the mediating variable must have a significant variation on the dependent variable (Path *M* to *Y* is significant)
iii. the independent variable must have a significant variation on the dependent variable (Path *A* to *Y* is significant)
iv. when the previous paths are controlled for (i.e., the mediator variable and independent variable are regressed on the outcome variable), a previous significant relationship between *A* and *Y* is no longer significant

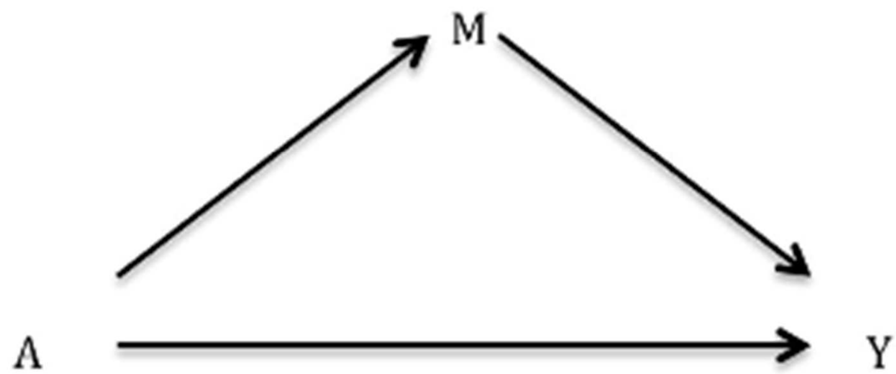


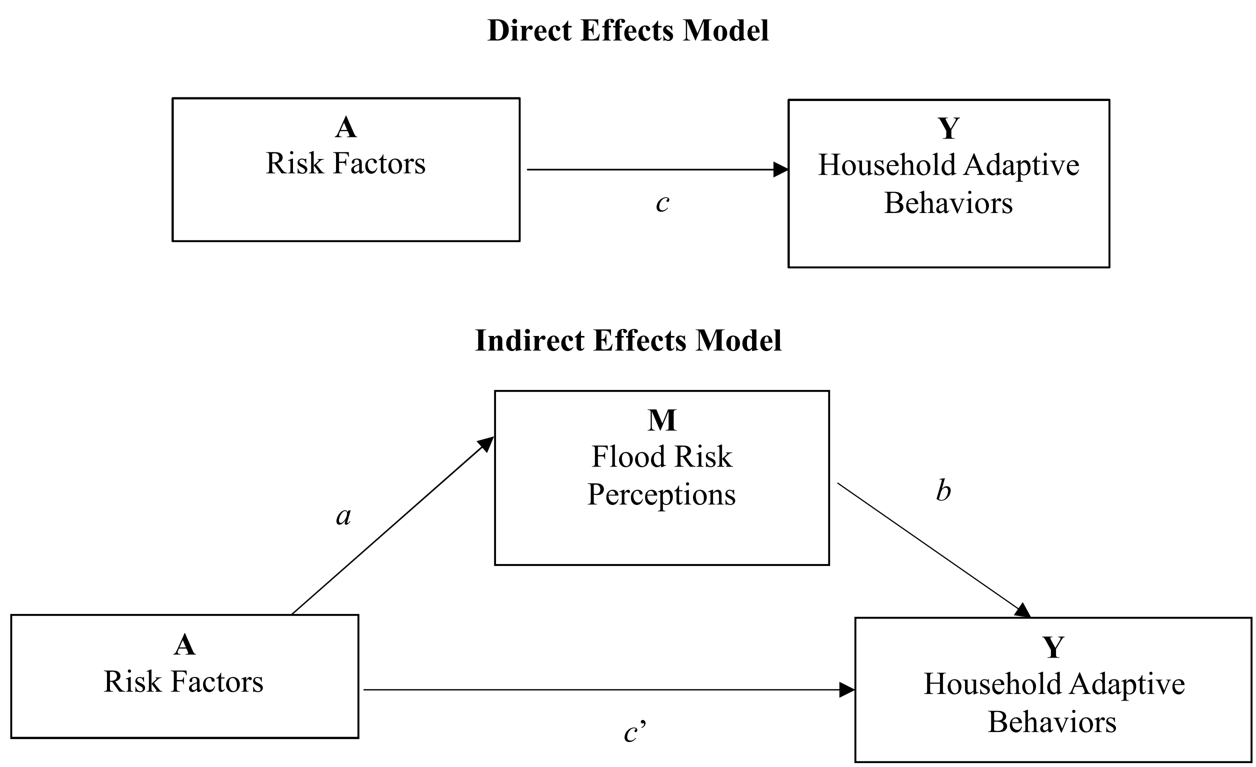
Figure 5. Mediation Model from Baron and Kenny (1986)

To test the mediating effect of a variable *M,* on the explanatory relationship between a set of *A* independent variables and *Y* the dependent variable (see Figure 6). Path *C*' shows the direct effect of the vector *A* and the mediating variable *M* (paths *A* and *B*) on the dependent variable *Y*. The essence of the mediating model is to test the difference between paths *C* and *C*'. When the paths are the same, then the variable *M* does not mediate the relationship. If paths *A* and *B* are significant, then partial mediation exists (Baron & Kenny, 1986). Therefore, the direct, indirect, and total effects can be found by estimating the following paths:

a) direct effect: $= c$
b) indirect effect: $(a \times b)$
c) total effect: $(a \times b) + c$

Based on a review on the more recent mediation literature, there is a consensus amongst scholars that when requirements (i) and (ii) are met in establishing mediation, requirements (iii) and (iv) are not necessary (MacKinnon, 2012). This is because the effect of *A* on *Y* may not be significant when direct and mediated effects have opposite signs. Once clarified, the amount of mediation that exists in the relationship (or the indirect effect) can be determined using the Sobel z-test (1982).

Figure 6. Direct and Indirect Effects Models



Step 2 – Testing Average Causal Mediation and Direct Effects

After testing for mediation amongst the various relationships, the data were analyzed to calculate the average causal mediation effects and direct effects. This study moved beyond traditional methods of calculating mediation effects by using the potential outcomes framework (Rubin, 2005). Whereas the traditional approach to mediation calculates the effect of an observed independent variable on an observed dependent variable via an observed mediating variable, the potential outcomes framework calculates the average causal mediation effect (ACME) and average direct effect (ADE) for various types of data. The –*mediation*- package in STATA calculates the ACME and ADE by simulating predicted values of the mediator and outcome variable that are not observed. For example, to calculate the ACME or indirect effect, the –*mediation*- package uses the following equation:

$$\delta_i(t) \equiv Y_i\{t, M_i(1)\} - Y_i\{t, M_i(0)\}$$

The following notations are used to calculate the indirect effect: $T_i = 1$ is the treatment variables (independent variable), the observed mediator $M_i(1)$, the control mediator $M_i(0)$, and the outcome variable Y_i.

The ADE is calculated using the following equation:

$$\zeta_i(t) \equiv Y_i\{1, M_i(t)\} - Y_i\{0, M_i(t)\}$$

This equation above examines the change in each unit *i* and each treatment variables. These equations allow the research to calculate the average mediation effects sizes of the outcome variable using control conditions for the mediator while holding the independent variable constant, resulting in an ACME. Essentially, the potential outcomes framework provides a "what-if" comparison if the mediating variable did not occur (see Rubin, 2005, for more details). Additionally, this allows for the researcher to calculate the causal quantity in the change of the outcome variable using control conditions for the independent variable while holding the mediating variable constant, resulting in an ADE (See Hicks and Tingley (2012) for additional details).

Step 3 – Testing Casual Framework of Sequential Ignorability

In the social sciences, the framework of linear regression models has been widely used to formulate and understand mediation effects. However, linear regression does not consider a casual framework and does not permit sensitivity analysis with respect to the assumption of sequential ignorability. Imai et al. (2010) posits that sequential ignorability consists of two assumptions: (a) conditional on the observed pretreatment covariates, the treatment is independent of all potential values of the outcome and mediating variables, and (b) the observed mediator is independent of all potential outcomes given the observed treatment and pretreatment covariates. Simply put, first, there are no unobserved confounders of the relationship between the independent variable and mediator (X->M), the relationship between the meditator and dependent variable (M->Y), and the relationship between the independent variable and dependent variable (X->Y). Sensitivity analysis quantifies the degree of sequential ignorability violation as the correlation between the error terms of the mediator and outcome models, and then calculating the true values of the average causal mediation effect for given values of this sensitivity parameter, ρ (rho). The sequential ignorability assumption must be satisfied in order to identify the average causal mediation effects.

Because sequential ignorability cannot be directly tested, sensitivity analysis provides an effective method for probing the plausibility of a non-refutable assumption (i.e., sequential ignorability). The goal of sensitivity analysis is to quantify the degree to which the key assumption of no unmeasured confounders (sequential ignorability) must be violated for a researcher's original conclusion to be reversed. If an inference is sensitive, a slight violation of the assumption may lead to substantively different conclusions. Given the importance of sequential ignorability, it has been argued that when observational data are employed, a sensitivity analysis should always be carried out (Imai et al. 2010a). As a result, sensitivity analysis is essential in order to examine the robustness of empirical findings to the possible existence of an unmeasured confounder.

Measures

Dependent Variables

The research question seeks to explain the degree of which flood risk perceptions mediate the relationship between risk factors and adaptive behaviors of households. The dependent variables of this study focus on actual adaptive behaviors that the household had undertaken which are expected to provide a stronger test of what directly and indirectly influences these adaptive behaviors. The survey asks each household to indicate which behaviors they have completed. The three dependent variables for this study are 1) if a change was made to a household behaviors which is a structural measure structural, 2) if the household purchased flood insurance which is a non-structural, and 3) a summative index of household adaptive structural and non-structural behaviors. These behaviors were captured in the survey data by the following questions, "Have you made any changes or investments to your home or property in response to flooding in the City of Portsmouth?" which is labeled "cha2home" and "Does your home have an insurance policy with the government's National Flood Insurance Program?" which is labeled "NFIP." Both questions were coded as 1=Yes and 0=No. The last dependent variable "index" was constructed by combing the two item-measure. The behaviors were summed into a behavioral index using "1" if the behavior had been performed and "0" if it had not been performed, resulting in a summed measure ranging from 0 to 2. This index score is reflective of the portfolio of measures that households create as they adopt measures to adjust to the impacts of flooding. This approach is similar to other risk perception and behavior studies (Martin et al., 2009).

Mediating Variables

As stated in the conceptual framework, flood risk perceptions are assumed to act as an intervening mechanism where various risk factors influence flood risk perceptions, and flood risk perceptions then influence household adaptive behavior. Given that risk perceptions often reflect different dimensions of risk (e.g., severity, intensity, frequency), several preliminary analyses of the data were conducted to establish the number of risk dimensions that are reflected in the survey data. Following the standard procedure of the psychometric paradigm where mean values of variable indicators are used to compare differences across groups or associations between relationships, the reliability of the flood risk perception index measures was analyzed (Grothmann & Reusswig, 2006; Kellens et al., 2011; Slovic et al., 1986). A Cronbach alpha coefficient was calculated. Cronbach alpha is a test that measures the internal consistency or reliability of a single construct, and observations are independent of each other. The Cronbach's alpha coefficient was evaluated using the guidelines suggested by Taber (2018). The items chosen for the flood risk perception scale based on face validity were:

- “Do you think flooding in the City of Portsmouth in general will increase, stay the same, or decrease in the next 20 years?” (RiskPerception1)
- “Thinking ahead about 20 years, do you believe your home specifically will have flood water come into the living area at least one time?” (RiskPerception2)
- “The City of Portsmouth is already experiencing the impact of sea level rise” (RiskPerception3)
- “The sea level around the City of Portsmouth will rise at least one and a half feet over the next 40 years” (RiskPerception4)
- “Sea level rise will negatively impact the economic opportunities for citizens of the City of Portsmouth” (RiskPerception5)

The five-item measure had a Cronbach’s alpha coefficient of 0.65, indicating an acceptable level of reliability (Taber, 2018). This means that these five items adequately measure flood risk perceptions.

To further validate the five-items accurately measure flood risk perceptions, a Principal Component Analysis (PCA) was conducted to determine commonality amongst the five constructs. PCA is a multivariate statistical technique used to assess and identify any underlying relationships among a set of scale variables.

In determining the number of components, the observed eigenvalues were calculated from the Pearson correlation matrix with the diagonal being replaced by the squared multiple correlations (Ledesma & Valero-Mora, 2007; Montanelli & Humphereys, 1976) to estimate the communalities (DiStefano, Zhu, & Mindrila, 2009; Stewart & Ware, 1992). The Kaiser criterion determined the number of components to retain. The Kaiser criterion identifies the number of factors in the model will be equal to the number of observed eigenvalues that have a value greater than one. The factor structure was assessed using a maximum likelihood estimation. A chi-square goodness-of-fit test will be conducted to determine the fit of the model. The factor loadings will implement criterion used by Comerey and Lee (2013) for factor interpretation. The factor structure will be examined by the precedents and rules Costello and Osborne (2005) have laid out.

To assess the factorability of the data, Pearson correlations were calculated to determine the inter-correlations for each variable. All variables had at least one correlation coefficient greater than .30 and appeared to be suitable for the analysis. To assess multicollinearity, the determinant of the correlation matrix was calculated. The value of the determinant for the correlation matrix was 0.469, indicating that there is little multicollinearity in the data. The observed eigenvalues were extracted from the correlation matrix with the diagonal of the matrix being replaced by each variable's squared multiple correlations (Ledesma, 2007; Montanelli & Humphereys, 1976) to estimate each variable's commonality (DiStefano, Zhu, & Mindrila, 2009; Stewart & Ware, 1992).

Figure 7 shows the scree plot along with the Kaiser criterion for determining the number of significant components. Looking at Figure 7, there was one factor that had an eigenvalue greater than one. However, it only accounted for 43% of the variance in the data with an eigenvalue of 2.18. The second factor had an eigenvalue of .958, which is close to the Kaiser criterion of retaining factors that have an eigenvalue greater than 1. The component also explained 19% of the variance. Cumulatively, the two components explain approximately 63% of the variance in the data. The principal component analysis summary is shown in Table 2. A Chi-square goodness of fit test was conducted to determine if the one-factor model fit the data perfectly, $\chi^2(5) = 27.41$, $p < .001$. This indicates that the one-factor model did not adequately depict the data.

The following variables had acceptable loadings for Component 1: perceptions of the severity of flooding Portsmouth had a loading of .53 (RiskPerception3), perceptions of the severity of future flooding in Portsmouth had a loading of .52 (RiskPerception4) and perceptions of the negative economic impact of flooding in Portsmouth had a loading of .48 (RiskPerception5). The following variable had a low factor loading: perceptions of flooding increasing, staying the same, or decreasing over the next 20 years had a loading of .37 (RiskPerception1). The following variables had poor loadings for Component 1: perceptions of a households' personal consequences to the impacts of flooding had a loading of .36 (RiskPerception2). However, RiskPerception2 had a high loading for Component 2, .81. The component analysis loadings are shown in Table 5.

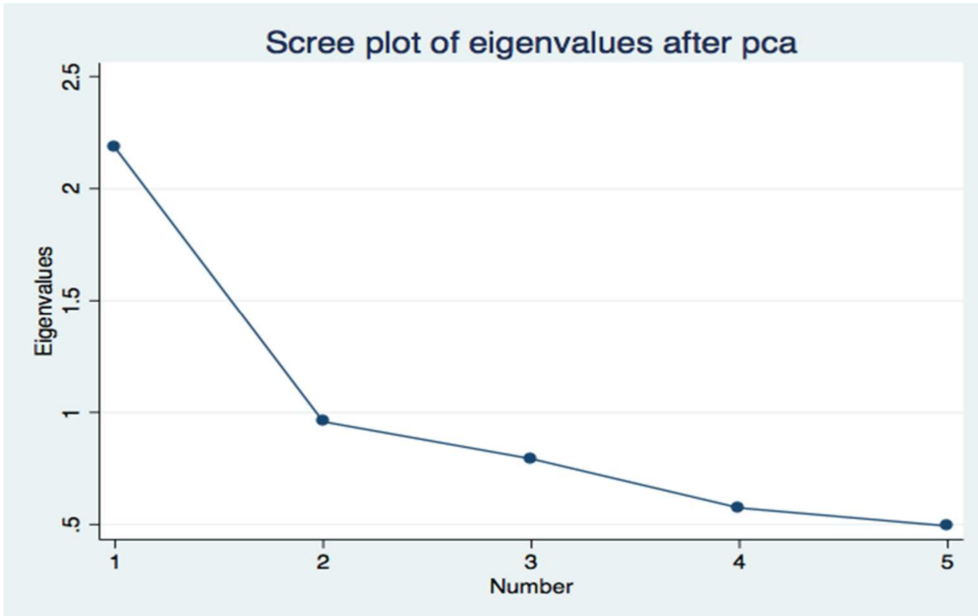


Figure 7. Scree plot of PCA eigenvalues

Table 4. Summary of PCA Results

Component	Eigenvalue	% of variance	Cumulative %
1	2.1817	43.63	43.63
2	.9582	19.17	62.80

Note: $\chi^2(5) = 27.41$, $p < .001$.

Table 5. Component Loadings from Principal Component Analysis

Variable	Component 1	Component 2
RiskPerception1	0.37	0.36
RiskPerception2		0.80
RiskPerception3	0.53	0.22
RiskPerception4	0.52	0.18
RiskPerception5	0.48	0.40

Note: Values < .32 were suppressed

After review of the PCA results, there were two possible components based on the five survey items. Theoretically, this made sense as Perception1, Perception3, Perception4, and Perception5 were reflective of the magnitude dimension of a risk. Although Perception1 had a factor loading of .37, the question was retained as it relates to the magnitude of flooding. This aligns with PMT where individuals assess perceived severity in the threat appraisal cognitive process. These items are contextually relevant as flooding is expected to be exacerbated by changes to sea level rise, and are similar to questions asked in previous flood risk questionnaires (Armaş & Avram, 2009; Kellens et al., 2011). Perception2 theoretically aligned with the dimension of perceived consequences of the impacts of flooding. A second reliability test was run for Perception1, Perception3, Perception4, and Perception5 resulting in a Cronbach alpha score of .68, reflecting an acceptable level of internal reliability. Based on the PCA results, two components were retained. The two component scores were named "severity" for component one and "conseq" for component two.

Independent Variables

There are 12 independent variables used in this study. The risk factors are measured using single-item indicators from the survey that are consistent with the conceptual framework. The independent variables collected in this survey reflect various risk factors (characteristics and attributes) of both the individual respondent and overall household. To be consistent with the conceptual framework, the indicators variables correspond with at least one category of a risk factor. The risk factors from the framework are personal characteristics, proximity, experience, locus of responsibility, and knowledge of flooding. See Table 6 for a list of the variables with their associated variable label, operationalization, and survey item from the survey data.

The respondent's attributes and characteristics (e.g., resident tenure, risk perceptions) are used in the data analysis as the survey asks, "May I speak with a member of the household that is at least 18 years old?" The respondents of reflect either partial or full attributes of their household. Given that the unit of analysis is households, both respondent characteristics as well as overall household characteristics (e.g., annual household income) were collected that reflect overall household attributes and characteristics.

Proximity

Four variables were chosen from the dataset to analyze a household's proximity to a large body of water. Physical exposure to a flood hazard is often determined by a resident's distance from a body of water or residing in a designated flood zone. Previous studies have shown that individual and household risk perceptions influence adaptive behavior (Lujala, Lein, & Rød, 2015; Zhang, Hwang, & Lindell, 2010). The survey asked households to report their street location. These data were used and geocoded to the nearest residential cross street. The data were then stratified into three strata: 100 meters from the coastline, 200 meters from the coastline, and 300 meters from the coastline. The fourth variable was created by combining the geocoded data from a household's location using a geographical information system (GIS) software in concert with flood zone data. If a household was located in an AE flood zone, an area that has a 1% probability of flooding each year (also known as the 100-year floodplain), they were coded as a "1". These indicators allow the research to assess the extent to which a household's distance from a coastline or placement in an AE zone may influence their flood risk perceptions or adaptive behavior. These variables are labeled in their respective orders as "meter100", "meter200", "meter300", and "AEzone."

Experience

Three indicators of direct experience with flooding were chosen from the dataset to analyze the influence of experience on risk perceptions and household adaptive behavior. Previous experience with flooding has been consistently shown to have a significant influence in shaping risk perceptions and adaptive behaviors. (Ho et al., 2008; Knocke & Kolivras, 2007; Lave & Lave, 1991; Siegrist & Gutscher, 2006, 2008). The first survey question asks, "How often does either the street in front of your home or the streets near your home flood?" and responses were coded as 4 = More than once a month, 3 = Couple of times a year, 2 = Once a year or less, and 1 = Rarely if ever. This variable is labeled as "streetflood" in the data analysis. The second question asks, "While living in Portsmouth, has your household suffered any property or car damage due to flooding?" and responses were coded as 1 = Yes and 0 = No. This question is labeled "sufferdam." The third question asks, "Have you or a member of your household been unable to get either in or out of your neighborhood because of flooding within the past year?" and responses were coded as 1 = Yes and 0 = No. This question is labeled "InAndOut."

Knowledge of Flooding

One indicator variable from the dataset was used to analyze a household's knowledge of flooding. More recently, risk communication scholars are attempting to understand if individuals and households associated flooding with climate change and sea level rise. In coastal communities increased flooding is often a result of sea level rise (Nicholls & Cazenave, 2010), particularly in the Hampton Roads region of Virginia where the city of Portsmouth is located (Atkinson, Ezer, & Smith, 2012; Kleinosky et al., 2007). Currently, the literature reports mixed findings on household's knowledge of flooding and sea level rise and its impacts on their risk perceptions or household adaptive behaviors. The usage of the term sea level rise in local planning and policy in Portsmouth warrants the need to investigate if and how households relate flooding with sea level rise to communicate the severity of their changing environment (City of Portsmouth, 2019; Hampton Roads Planning Commission, 2018).

The survey item chosen from the dataset asks, "Sea level rise and neighborhood flooding in the City of Portsmouth are related" and responses were coded as 4 = strongly agree, 3 = Agree, 2 = Disagree, 1 = Strongly Disagree, and labeled as "knowledge."

Locus of Responsibility

To measure a household's locus of responsibility, we examine their perceived responsibility to protect themselves against flooding. Martin et al. (2009) analyzed a conceptual model and found that a household's perceived level of responsibility, mediated by risk perceptions, was correlated with reducing their risk associated with wildfires. The survey item chosen from the data asks, "It is the individual household's responsibility to take steps to adapt to potential future flooding," and responses were coded as 4 = strongly agree, 3 = Agree, 2 = Disagree, 1 = Strongly Disagree. The variable was labeled as "respon."

Household Characteristics

Household tenure, income, and race have been found to influence risk perceptions. However, household tenure or race rarely influence household adaptive behavior. To examine household tenure, the survey item chosen asks, "Roughly, how many years have you lived in your current home?" and responses were recorded as continuous.

To examine race, the survey item chosen asks, “How would you characterize the overall race or ethnicity of your household?” and responses were recorded as 1 = White/Anglo/Caucasian, 2 = Black/African-American, 3 = Hispanic/Latino/Puerto Rican/Cuban/Mexican-American, 4 = Filipino, 5 = Mixed Black-White, 6 = Mixed Black-Hispanic, and 7 = Mixed Hispanic-White. The responses were recoded and collapsed into two categories where White remained the same and coded as “1”, and all other categories were combined and recoded as 0 = Non-White. White was chosen as the reference category as it had the most number of observations compared to the other groups.

To examine household income, the survey asks, “What is your total annual household income?”, and responses were recorded as 1 = Below $10,000, 2 = $10,001-$25,000, 3 = $25,001-$40,000, 4 = $40,001-$60,000, 5 = $60,001-$80,000, 6 = $80,001-$100,00, 7 = $100,001-$120,000, 8 = $120,001-$140,000, 9 = $140,001-$160,000, and 10 = Over $160,000.

Table 6. Variable Constructs and Survey Items

Variable Name	Risk Factor	Operational Definition	Survey Item(s)	Data Type
tenure	Personal Characteristic	The number of years the respondent reported living in Portsmouth	How many years have you lived in Portsmouth in total?	interval
race	Personal Characteristic	Reported race of overall household	How would you characterize the overall race or ethnicity of your household?	categorical
income	Personal Characteristic	Report annual income per household	What is your total annual household income?	ordinal
responsibility	Locus of Responsibility	The attitude an individual takes on their level of responsibility on things that can't be controlled by humans	It is the individual household's responsibility to take steps to adapt to potential future flooding.	ordinal
knowledge	Knowledge	The information a household knows regarding the connection between flooding and sea level rise	Sea level rise and neighborhood flooding in the City of Portsmouth are related	ordinal
streetflood	Experience	Past experience with flood events	How often does either the street in front of your home or the streets very near your home flood?	ordinal
sufferdam	Experience	Reported damage to household as a result of flood impacts	While living in Portsmouth, has your household suffered any property or car damage due to flooding?	categorical

Variable Name	Risk Factor	Operational Definition	Survey Item(s)	Data Type
InAndOut	Experience	The ability to get in and out of your neighborhood	Have you or a member of your household been unable to get either in or out of your neighborhood because of flooding within the past year?	ordinal
100meter	Proximity	The amount of distance measured in feet a household is from the city's coastline	Household address data were geocoded to examine their proximity to the coastline and coded 1 if within 100 meters of the coastline and 0 if household is not located within 100 meters of the coastline	binary
200meter	Proximity	The amount of distance measured in feet a household is from the city's coastline	Household address data were geocoded to examine their proximity to the coastline and coded 1 if within 200 meters of the coastline and 0 if household is not located within 200 meters of the coastline	binary

Variable Name	Risk Factor	Operational Definition	Survey Item(s)	Data Type
300meter	Proximity	The amount of distance measured in feet a household is from the city's coastline	Household address data were geocoded to examine their proximity to the coastline and coded 1 if within 300 meters of the coastline and 0 if household is not located within 300 meters of the coastline	binary
		Perceived magnitude of the impacts of flooding	1)Looking ahead, do you think flooding in the City of Portsmouth in general will increase? stay the same, or decrease in the next 20 years?	ordinal
			3)The City of Portsmouth is already experiencing the impact of sea level rise.	ordinal
			4)The sea level around the City of Portsmouth will rise at least one and a half feet over the next 40 years.	ordinal
			5)Sea level rise will negatively impact the economic opportunities for citizens of the City of Portsmouth.	ordinal

Variable Name	Risk Factor	Operational Definition	Survey Item(s)	Data Type
		Perceived personal consequences of the impacts of flooding	2)Thinking ahead about 20 years, do you believe your home specifically will have flood water come into the living area at least one time?	ordinal
index		An action(s) that a household engages in to reduce the impacts or adjust to flooding. The following two questions were combined, ranging from 0-2	Does your home have an insurance policy with the government's National Flood Insurance Program?	binary
			Have you made any changes or investments to your home or property in response to flooding in the City of Portsmouth?	binary

Missing Data and Recoding

All variables were inspected for missing data. For each question where a participant responded with “Don’t know” or “Refuse” were initially coded with numerical values of 88 and 99. These numerical values were recoded as “.” in STATA to reflect a non-response, or missing data.

Regression Models

Three models were fit and tested using individual ordinary least squares (OLS) regression equations. The first model, “Model 1” contains four equations. Equation one includes twelve independent variables (risk factors), and one mediating variable (severity). This model was constructed by the researcher for the purpose of examining the indirect and direct effects of risk factors on the combined behavioral index via perceived severity of flooding. The equation includes one outcome variable (index), one mediating variable (severity), and twelve risk factors. This model was constructed by the researcher for the purpose of examining the indirect and direct effects of risk factors on the combined behavioral index via perceived consequences of flooding. The third equation includes the dependent variable (conseq), and twelve risk factors. The fourth equation includes the dependent variable (index), a mediating variable (conseq), and twelve risk factor variables. Model 1 equations are graphed a path model in Figure 8.

The second model, “Model 2” contains four equations. Equation one includes twelve independent variables (risk factors), and one mediating variable (severity). This model was constructed by the researcher for the purpose of examining the indirect and direct effects of risk factors on the combined behavioral index via perceived severity of flooding. The equation includes one outcome variable (cha2home), one mediating variable (severity), and twelve risk factors. This model was constructed by the researcher for the purpose of examining the indirect and direct effects of risk factors on the combined behavioral index via perceived consequences of flooding. The third equation includes the dependent variable (conseq), and twelve risk factors. The fourth equation includes the dependent variable (cha2home), a mediating variable (conseq), and twelve risk factor variables. Model 2 equations are graphed a path model in Figure 9.

The third model, "Model 3" contains four equations. Equation one includes twelve independent variables (risk factors), and one mediating variable (severity). This model was constructed by the researcher for the purpose of examining the indirect and direct effects of risk factors on the combined behavioral index via perceived severity of flooding. The equation includes one outcome variable (NFIP), one mediating variable (severity), and twelve risk factors. This model was constructed by the researcher for the purpose of examining the indirect and direct effects of risk factors on the combined behavioral index via perceived consequences of flooding. The third equation includes the dependent variable (conseq), and twelve risk factors. The fourth equation includes the dependent variable (NFIP), a mediating variable (conseq), and twelve risk factor variables. Model 3 equations are graphed a path model in Figure 10. In summary, the following models and equations are estimated using the following equations:

<u>Model 1</u>

Equation 1: severity= $f(\sum_{i=1}^{12} \text{Risk factor}_i)$

Equation 2: index = $f(\sum_{i=1}^{12} \text{Risk factor}_i,\ \text{severity})$

Equation 3: conseq= $f(\sum_{i=1}^{12} \text{Risk factor}_i)$

Equation 4: index = $f(\sum_{i=1}^{12} \text{Risk factor}_i,\ \text{consequences})$

<u>Model 2</u>

Equation 1: severity= $f(\sum_{i=1}^{12} \text{Risk factor}_i)$

Equation 2: cha2home = $f(\sum_{i=1}^{12} \text{Risk factor}_i,\ \text{severity})$

Equation 3: conseq= $f(\sum_{i=1}^{12} \text{Risk factor}_i)$

Equation 4: cha2home = $f(\sum_{i=1}^{12} \text{Risk factor}_i,\ \text{consequences})$

<u>Model 3</u>

Equation 1: severity= $f(\sum_{i=1}^{12} \text{Risk factor}_i)$

Equation 2: NFIP = $f(\sum_{i=1}^{12} \text{Risk factor}_i,\ \text{severity})$

Equation 3: conseq= $f(\sum_{i=1}^{12} \text{Risk factor}_i)$

Equation 4: NFIP = $f(\sum_{i=1}^{12} \text{Risk factor}_i,\ \text{consequences})$

OLS regressions were used to fit the regression equations for models 3 and 4 although the dependent variables "cha2home" and "NFIP" were binary. OLS regression was preferred over logistic regression for the following reasons. First, the regression models were used to identify and fit the hypothesized causal pathways from the hypothesized conceptual framework. The conceptual framework seeks to explain variation in the dependent variable versus predict new or future observations. Explanatory modeling seeks to justify or support a causal relationship. While both explanatory and predictive modeling as necessary for theory building and testing, this study is explorative and the conceptual framework is newly developed from the literature. Therefore, I found it necessary to first analyze the data using OLS regression as advised by Shmueli (2010). Second, logit coefficients estimate the effect of a one unit increase in the independent variable on the dependent variable (unstandardized coefficients) while OLS estimates can adjust for differences in the scales of independent variables (standardized coefficients). After running logistic regression models 3 and 4, there were only marginal differences that did not impact the overall significance of the model or coefficient values.

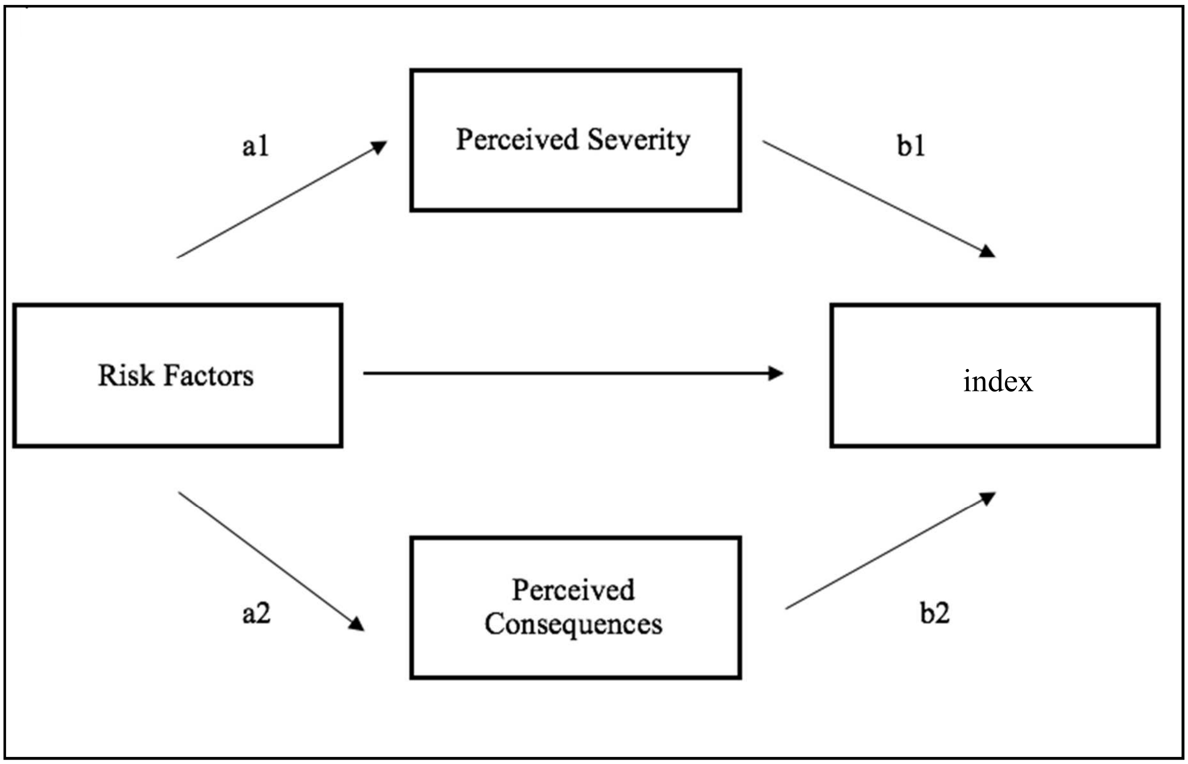


Figure 8. Path Diagram of Combined Household Adaptive Behavior Index

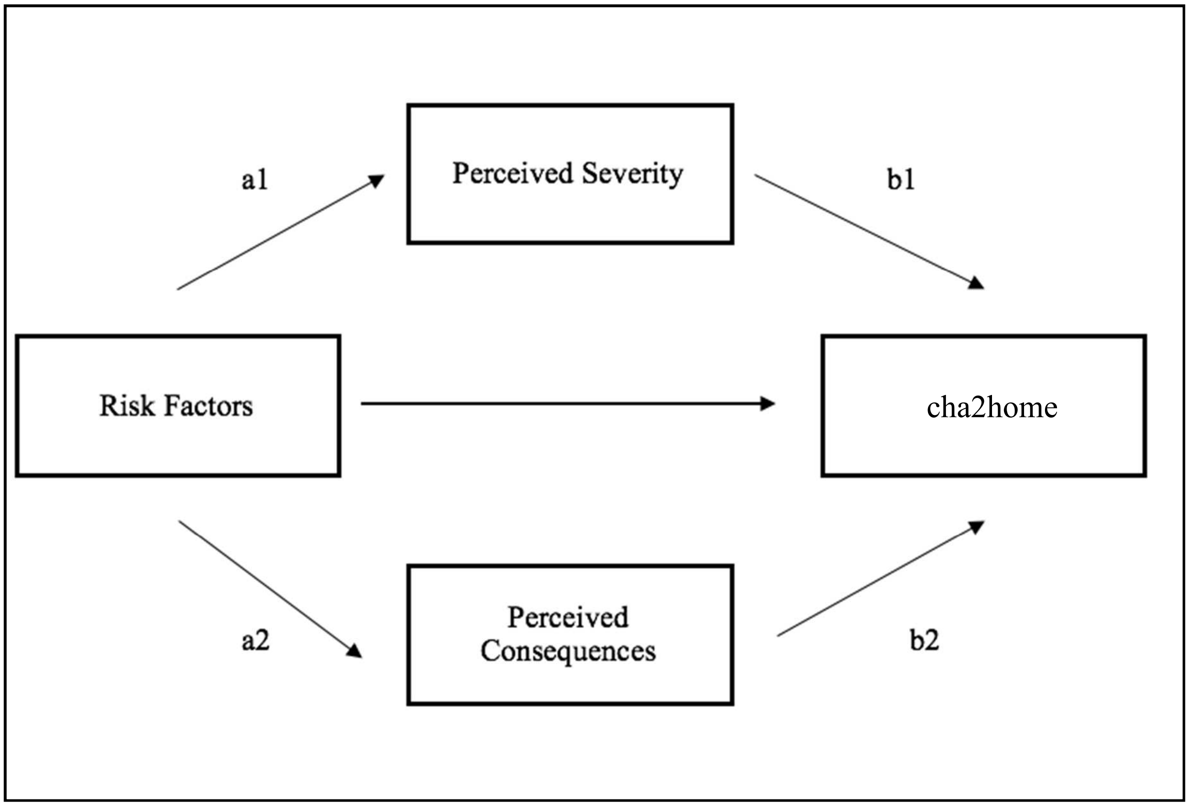


Figure 9. Path Diagram of Change Made to Home

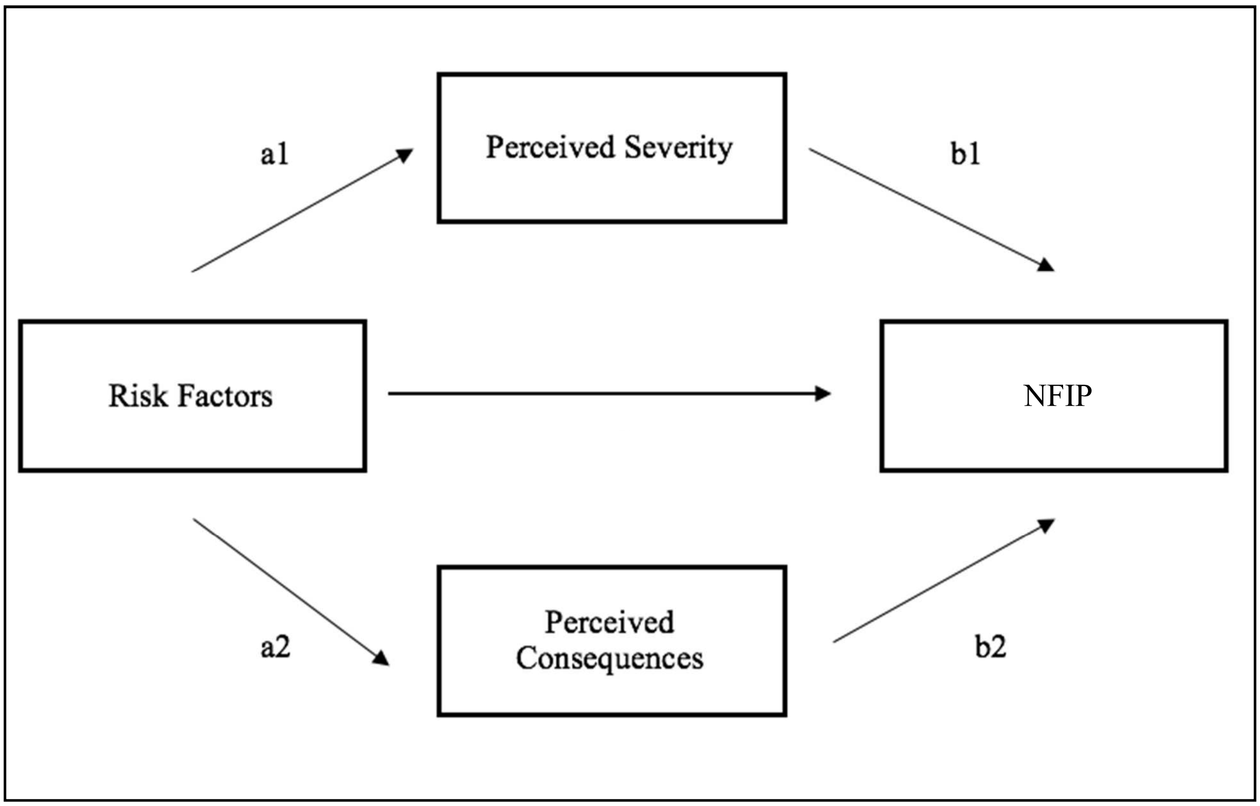


Figure 10. Path Diagram of Purchased NFIP

5. ANALYSIS AND RESULTS

Description and Summary

The description of the dataset is described in Table 8. The independent, mediating, and dependent have already been discussed in Chapter 4. The descriptive statistics are listed in Table 9. The first four variables measure a household's proximity to a shoreline or if they reside in a designated flood zone. The data reflect that 10% of the households were located in a designated flood zone (*M* = .10, *SD* = .30). Approximately 15% of the households lived 100 meters or less from the shoreline (*M* = .15, *SD* = .36), 34% were located 200 meters from the shoreline (*M* = .34, *SD* = .34), and 46% were located 300 meters from the shoreline (*M* = .46, *SD* = .47). The next several variables measure experience with flooding. More than half of those who responded reported that they experience a moderate level of flooding near their home (*M* = 2.4, *SD* = 1.1). Approximately 38% of the households reported that they had difficulty leaving or entering their neighborhood within the past month due to flooding (*M* = .38, *SD* = .48). Nearly 20% of the sample reported having experienced damage to their home or property as a result flooding (*M* = .18, *SD* = .38). Knowledge of flooding had a mean value of 3 which reflects that in a many of households reported that they agree that neighborhood flooding and sea level rise are related issues. The locus of responsibility measure had a mean value of 2.4, reflecting that more than half of the households agree that flood adaption is the responsibility of the household. Household characteristics reflect that households on average lived in their current home for approximately 20 years (*M* = .19, *SD* = 15.00), more than half reported that their households were White (*M* = .59, *SD* = .49), and the average mean value of annual household income was 4.9. Approximately 15% of households reported that they had made a change to their home or property as a result of flooding (M = .15, SD = .36), 27% purchased flood insurance (M = .27, SD = .44), and the average mean value reported for households who have adopted one, two, or no adaptive behaviors was .4 (*SD* = .61).

Table 7. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
AEzone	1,582	.1011378	.3016064	0	1
meter100	1,582	.1561315	.3630947	0	1
meter200	1,582	.340708	.4740972	0	1
meter300	1,582	.4671302	.4990762	0	1
streetflood	1,551	2.452611	1.182198	1	4
InAndOut	1,581	.3839342	.4864961	0	1
sufferdam	1,581	.1859583	.3891961	0	1
knowledge	1,474	3.077341	.633519	1	4
respon	1,504	2.409574	.725774	1	4
tenure	1,576	19.66942	15.00694	0	87
race	1,495	.5926421	.4915069	0	1
income	1,240	4.974194	1.964408	1	10
severity	1,095	-1.34e-09	1.000001	-2.800	1.324
conseq	1,095	-3.27e-10	1.000001	-.7823	1.277
cha2home	1,579	.1589614	.3657559	0	1
NFIP	1,430	.2713287	.4448008	0	1

index	1,429	.4275717	.6113731	0	2

Mediation Tests Analysis

This study aims to evaluate the mediating (or indirect) role of flood risk perceptions in explaining household adaptive behaviors. Therefore, individual regression equations were used to fit and model the data based on the hypotheses mentioned in Chapter 4 to first establish if mediation exists which consists of testing for a significant relationship between an independent variable and mediating variable, and a significant relationship between the mediating variable and outcome variable. The results of the mediation tests for each model are presented below.

Step 1 - Results from Mediation Tests

To test if the relationship between various risk factors on household adaptive behavior was mediated by flood risk perceptions, I examined if mediation exists amongst the relationships. I follow the MacKannon's (2012) revised approached to Baron and Kenny's (1986) requirements for establishing mediation mentioned in Chapter 4.The Tables 10 and 11 provide a summary of the mediation and Sobel tests results.

The results show that a household's perceived consequences of flooding partially mediate several relationships. A household's experience, knowledge of flooding, responsibility of flooding, and race have a statistically significant relationship with their perceived consequences, and their perceived consequences influence their adaptive behaviors.

Table 8. Summary of Mediation Results

	index		cha2home		NFIP	
	severity	conseq	severity	conseq	severity	conseq
AEzone	-	-	-	-	-	-
meter100	-	-	-	-	-	-
meter200	-	-	-	-	-	-
meter300	-	-	-	-	-	-
streetflood	-	-	-	-	-	-
InAndOut	-	**Partial Mediation**	-	-	-	-
sufferdam	-	**Partial mediation**	-	-	-	-
knowledge	-	**Partial mediation**	-	-	-	-
respon	-	**Partial mediation**	-	-	-	-
tenure	-	-	-	-	-	-
income	-	-	-	-	-	-
race	-	**Partial mediation**	-	-	-	-

Note: " – " denotes that no support

Table 9. Summary of Sobel Test

	InAndOut	sufferdam	knowledge	respon	race
Perceived Consequences	1.664	2.19***	1.885***	-1.831	-1.908

Note: *** p<0.001, ** p<0.01, * p<0.05

Models 1 – index as dependent variable

In the first regression model for Model 1, the 12 risk factors were regressed on the mediating variable "severity" to fit path a_1. The model was statistically significant, $F(12, 881) = 29.83$, $p < .05$. The first regression model was fit to examine path a_1. There was a positive and significant relationship between perceived severity and the ability to get in and out of their neighborhood ($\beta = 0.68$, $p < .05$), knowledge of flooding ($\beta = 0.52$, $p < .05$), and a significant and negative relationship between a household's locus of responsibility and perceived severity of flooding ($\beta = -0.08$, $p < .05$). The increase in participants reporting more difficulty getting in and out of their neighborhood led to an increase in a household's perception of the severity of flooding in Portsmouth. For those who more likely to agree that sea level rise and flooding were related also led to an increase in their perceived level of severity to flooding.

Next, the second regression model was run to fit and examine path b_1 *and c'*. The model was statistically significant, $F(13, 745) = 29.83$, $p < .05$. Although there were significant relationships that explained the dependent variable, living in a flood zone ($\beta = 0.21$, $p < .05$), experiencing street flooding ($\beta = 0.10$, $p < .05$), suffering damage to the home ($\beta = 0.24$, $p < .05$), household annual income ($\beta = 0.07$, $p < .05$), and household race ($\beta = 0.08$, $p < .05$), there was not a significant relationship between perceived severity and the dependent variable ($\beta = 0.01$, $p < .05$) which is the second step in establishing mediation, path b_1. However, significant and positive results indicate that as participants reported living in flood zones, experiencing increased street flooding, suffering damage to their homes, reported higher household annual incomes, and reported a White racial makeup of the home led to an increase in households engaging in adaptive behaviors.

In the third regression equation for Model 1, the 12 risk factors were regressed on the mediating variable "conseq" to fit path a_2. The model was statistically significant, F(12, 881) = 11.09, $p < .05$. There was a positive and significant relationship between perceived consequences of flooding and suffering damage to the home ($\beta = 0.22$, $p < .05$), the ability to get in and out of a neighborhood ($\beta = 0.74$, $p < .05$), knowledge of flooding ($\beta = 0.10$, $p < .05$), and a significant and negative relationship with a household's locus of responsibility to flooding ($\beta = -0.08$, $p < .05$) and household race ($\beta = -0.12$, $p < .05$). Households that reported that they have experienced damage to their home as a result of flooding, increased inability to get in and out of their neighborhoods, agreed that sea level rise and flooding were related issues led to an increase their level of perceived consequences to flooding. On the contrary, those who reported that they felt less individual responsibility to protect themselves against flooding led to less severe perceived consequences of flooding. Also, those who were more likely to report a non-White makeup of the household also led to lower levels of perceived personal consequences.

Next, the second regression model was run to fit and examine path b_2 *and c'*. The model was statistically significant, F(13, 745) = 14.52, $p < .05$. There was a significant relationship between perceived consequences of flooding and the dependent variable ($\beta = 0.08$, $p < .05$) (path b_2). This means that there is a relationship between a household's perceived consequences and their adaptive behaviors. Following the procedure for testing mediation where paths a_1 and b_1 must be significant, perceived consequences mediate the relationships between the following risk factors and household adaptive behaviors (sufferdam, InAndOut, knowledge, respon, and race).

Therefore, we can conclude that in Model 1, risk factors do not have an influence on adaptive behaviors of households via perceived severity of flooding. However, in we can conclude that perceived consequences mediate the relationship between various risk factors and household adaptive behaviors. See Tables 10 and 11 for standardized OLS regression coefficients.

Table 10. Standardized Coefficients for Equations 1 and 2 for Model 1

VARIABLES	(Eq:1) severity	(Eq:2) index
severity		0.00747
		(0.0246)
AEzone	0.116	0.437***
	(0.103)	(0.0721)
meter100	0.0896	0.0540
	(0.103)	(0.0711)
meter200	-0.0552	-0.0107
	(0.107)	(0.0750)
meter300	0.0764	0.0808
	(0.0934)	(0.0658)
streetflood	0.0214	0.0583***
	(0.0297)	(0.0207)
InAndOut	0.140**	0.00762
	(0.0673)	(0.0477)
sufferdam	-0.0228	0.387***
	(0.0765)	(0.0546)
knowledge	0.812***	0.0625
	(0.0464)	(0.0381)
respon	-0.121***	-0.0226
	(0.0420)	(0.0297)
tenure	0.00229	-0.000255
	(0.00215)	(0.00156)
income	0.00511	0.0250**
	(0.0157)	(0.0108)
race	0.0497	0.105**
	(0.0650)	(0.0460)
conseq		
Constant	-2.486***	-0.179
	(0.228)	(0.170)
Observations	824	759
Adjusted R^2	0.306	0.196

Note: Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

Table 11. Standardized Coefficients for Equations 3 and 4 for Model 1

VARIABLES	(Eq:3) conseq	(Eq:4) index
conseq		0.0528**
		(0.0224)
AEzone	-0.145	0.446***
	(0.113)	(0.0719)
meter100	0.114	0.0482
	(0.114)	(0.0708)
meter200	-0.0416	-0.00852
	(0.118)	(0.0747)
meter300	0.0644	0.0772
	(0.103)	(0.0655)
streetflood	0.0499	0.0563***
	(0.0327)	(0.0207)
InAndOut	0.152**	-0.000982
	(0.0743)	(0.0476)
sufferdam	0.554***	0.359***
	(0.0843)	(0.0557)
knowledge	0.159***	0.0599*
	(0.0512)	(0.0324)
respon	-0.120***	-0.0163
	(0.0463)	(0.0296)
tenure	0.000354	-0.000183
	(0.00237)	(0.00155)
income	-0.0233	0.0264**
	(0.0173)	(0.0108)
race	-0.255***	0.119**
	(0.0717)	(0.0461)
Constant	-0.277	-0.186
	(0.252)	(0.158)
Observations	824	759
Adjusted R^2	0.141	0.202

Note: Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

Model 2 – cha2home as dependent variable

In the first regression equation for Model 2, the 12 risk factors were regressed on the mediating variable “severity” to fit path a_1. The model was statistically significant, F(12, 881) = 29.83, $p < .05$. The first regression model was fit to examine path a_1. There was a positive and significant relationship between perceived severity of and the ability to get in and out of a neighborhood ($\beta = 0.68$, $p < .05$), knowledge of flooding ($\beta = 0.52$, $p < .05$) and a significant and negative relationship between a household’s locus of responsibility and their perceptions of the severity of flooding ($\beta = -0.08$, $p < .05$). These results mimic the results of Model 1.

Next, the second regression equation was run to fit and examine path b_1 *and c’*. The model was statistically significant, F(13, 810) = 10.90, $p < .05$. Although there were significant risk factors that explained changes made to a household, living in a flood zone ($\beta = 0.07$, $p < .05$), experiencing street flooding ($\beta = 0.12$, $p < .05$), suffering damage to the home ($\beta = 0.29$, $p < .05$), and household race ($\beta = 0.07$, $p < .05$), there was not a significant relationship between perceived severity and making a change to the home or property ($\beta = 0.01$, $p > .05$) which is the second step in establishing mediation in path b_1. Therefore, mediation does not exist between the risk factors and changes made to a home. However, there were several direct relationships. That explained if a household made a change to their home or property. Households that were White, located in a flood zone along, experienced more flood events, and reported higher income led to an increase in changes made to their home or property.

In the third regression equation for Model 3, the 12 risk factors were regressed on the mediating variable “conseq” to fit path a_2. The model was statistically significant, F(12, 881) = 11.09, $p < .05$. The first regression equation was fit to examine path a_2. There was a positive and significant relationship between perceived severity and suffering damage ($\beta = 0.26$, $p < .05$), the ability to get in and out of a neighborhood ($\beta = 0.07$, $p < .05$), knowledge of flooding ($\beta = 0.10$, $p < .05$), and a significant and negative relationship between a household's locus of responsibility and making a change to their home or property ($\beta = -0.088$, $p < .05$) and race ($\beta = -0.12$, $p < .05$).

Next, the fourth regression equation was run to fit and examine path b_2 *and c'*. The model was statistically significant, $F(13, 810) = 11.20$, $p < .05$. Although there were significant risk factors that explained changes made to a household, living in a flood zone ($\beta = 0.07$, $p < .05$), experiencing street flooding ($\beta = 0.11$, $p < .05$) suffering damage to a home ($\beta = 0.28$, $p < .05$), knowledge of flooding ($\beta = 0.07$, $p < .05$), household annual income ($\beta = 0.07$, $p < .05$), and household race ($\beta = 0.08$, $p < .05$), there was not a significant relationship between perceived consequences of flooding and making a change to a home or property ($\beta = 0.05$, $p < .05$) which is the second step in establishing mediation in path b_2.

Therefore, we can conclude that in Models 2 and 3, perceived severity nor perceived consequence have an indirect impact between risk factors and household that have only made changes to their property or home. See Tables 12 and 13 for standardized OLS regression coefficients.

Table 12. Standardized Coefficients for Equations 1 and 2 for Model 2

VARIABLES	(Eq:1) severity	(Eq:2) cha2home
severity		0.00294
		(0.0148)
AEzone	0.116	0.0901**
	(0.103)	(0.0434)
meter100	0.0896	-0.0543
	(0.103)	(0.0436)
meter200	-0.0552	-0.0150
	(0.107)	(0.0454)
meter300	0.0764	0.00813
	(0.0934)	(0.0395)
streetflood	0.0214	0.0402***
	(0.0297)	(0.0125)
InAndOut	0.140**	-0.00145
	(0.0673)	(0.0285)
sufferdam	-0.0228	0.279***
	(0.0765)	(0.0323)
knowledge	0.812***	0.0424*
	(0.0464)	(0.0230)
respon	-0.121***	0.00249
	(0.0420)	(0.0178)
tenure	0.00229	0.00110
	(0.00215)	(0.000908)
income	0.00511	0.0133**
	(0.0157)	(0.00663)
race	0.0497	0.0609**
	(0.0650)	(0.0275)
Constant	-2.486***	-0.242**
	(0.228)	(0.103)
Observations	824	824
Adjusted R^2	0.306	0.149

Note: Standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05

Table 13. Standardized Coefficients for Equations 3 and 4 for Model 2

VARIABLES	(Eq:3) conseq	(Eq:4) cha2home
conseq		0.0213
		(0.0134)
AEzone	-0.145	0.0935**
	(0.113)	(0.0433)
meter100	0.114	-0.0565
	(0.114)	(0.0436)
meter200	-0.0416	-0.0142
	(0.118)	(0.0453)
meter300	0.0644	0.00699
	(0.103)	(0.0394)
streetflood	0.0499	0.0392***
	(0.0327)	(0.0125)
InAndOut	0.152**	-0.00428
	(0.0743)	(0.0285)
sufferdam	0.554***	0.267***
	(0.0843)	(0.0331)
knowledge	0.159***	0.0414**
	(0.0512)	(0.0197)
respon	-0.120***	0.00469
	(0.0463)	(0.0178)
tenure	0.000354	0.00110
	(0.00237)	(0.000906)
income	-0.0233	0.0138**
	(0.0173)	(0.00662)
race	-0.255***	0.0664**
	(0.0717)	(0.0277)
Constant	-0.277	-0.243**
	(0.252)	(0.0965)
Observations	824	824
Adjusted R^2	0.141	0.151

Note: Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

Model 3 – NFIP as dependent variable

In the first regression equation for Model 3, the 12 risk factors were regressed on the mediating variable "severity" to fit path a_1. The model was statistically significant, F(12, 881) = 29.83, $p < .05$. The first regression model was fit to examine path a_1. There was a positive and significant relationship between perceived severity and the ability to get in and out of a neighborhood due to flooding ($\beta = 0.68$, $p < .05$), knowledge of flooding ($\beta = 0.52$, $p < .05$), and a significant and negative relationship between a household's locus of responsibility and their perceptions of the severity of flooding ($\beta = -0.09$, $p < .05$).

Next, the second regression equation was run to fit and examine path b_1 *and c'*. The model was statistically significant, F(13, 745) = 10.90, $p < .05$. Although there were significant risk factors that explained changes made to a household, living in a flood zone ($\beta = 0.01$, $p < .05$), living within 100 meters of the coastline ($\beta = 0.09$, $p < .05$), and suffering damage to the home ($\beta = 0.12$, $p < .05$), there was not a significant relationship between perceived severity of and purchasing flood insurance ($\beta = 0.01$, $p > .05$) which is the second step in establishing mediation in path b_1. See Tables 14 and 14 for OLS regression coefficients.

In the third regression equation for Model 3, the 12 risk factors were regressed on the mediating variable "conseq" to fit path a_2. The model was statistically significant, F(12, 881) = 11.09, $p < .05$. There was a positive and significant relationship between perceived severity of flooding and suffering damage to a home ($\beta = 0.26$, $p < .05$), the ability to get in and out of a neighborhood due to flooding ($\beta = 0.07$, $p < .05$), knowledge of flooding ($\beta = 0.10$, $p < .05$), and a significant and negative relationship between a household's locus of responsibility to flooding and making a change to their home or property ($\beta = -0.09$, $p < .05$) and household race ($\beta = -0.12$, $p < .05$).

Next, the fourth regression equation was run to fit and examine path b_2 *and c'*. The model was statistically significant, F(13, 745) = 11.20, $p < .05$. Although there were significant risk factors that explained if a household purchased flood insurance, living in a flood zone (β = 0.218, $p < .05$) and suffering damage to a home (β = 0.10, $p < .05$), there was not a marginal but not significant relationship between perceived consequences and purchasing flood insurance (β = 0.06, $p > .05$) which is the second step in establishing mediation in path b_2.

We conclude that perceived severity and perceived consequences do not mediate the relationships between risk factors and households that have only purchased flood insurance.

Table 14. Standardized Coefficients for Equations 1 and 2 for Model 3

VARIABLES	(Eq:1) severity	(Eq:2) NFIP
severity		0.00494
		(0.0185)
AEzone	0.116	0.317***
	(0.103)	(0.0541)
meter100	0.0896	0.104*
	(0.103)	(0.0533)
meter200	-0.0552	0.0113
	(0.107)	(0.0562)
meter300	0.0764	0.0621
	(0.0934)	(0.0493)
streetflood	0.0214	0.0158
	(0.0297)	(0.0155)
InAndOut	0.140**	0.0205
	(0.0673)	(0.0358)
sufferdam	-0.0228	0.132***
	(0.0765)	(0.0410)
knowledge	0.812***	0.0148
	(0.0464)	(0.0285)
respon	-0.121***	-0.0126
	(0.0420)	(0.0223)
tenure	0.00229	-0.000670
	(0.00215)	(0.00117)
income	0.00511	0.0102
	(0.0157)	(0.00813)
race	0.0497	0.0436
	(0.0650)	(0.0345)
Constant	-2.486***	0.0470
	(0.228)	(0.128)
Observations	824	759
R-squared	0.306	0.124

Note: Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05.

Table 15. Standardized Coefficients for Equations 3 and 4 for Model 3

VARIABLES	(Eq:3) conseq	(Eq:4) NFIP
conseq		0.0309
		(0.0168)
AEzone	-0.145	0.322***
	(0.113)	(0.0540)
meter100	0.114	0.101*
	(0.114)	(0.0532)
meter200	-0.0416	0.0125
	(0.118)	(0.0561)
meter300	0.0644	0.0600
	(0.103)	(0.0492)
streetflood	0.0499	0.0146
	(0.0327)	(0.0155)
InAndOut	0.152**	0.0156
	(0.0743)	(0.0358)
sufferdam	0.554***	0.116***
	(0.0843)	(0.0419)
knowledge	0.159***	0.0138
	(0.0512)	(0.0243)
respon	-0.120***	-0.00897
	(0.0463)	(0.0222)
tenure	0.000354	-0.000627
	(0.00237)	(0.00117)
income	-0.0233	0.0110
	(0.0173)	(0.00812)
race	-0.255***	0.0514
	(0.0717)	(0.0346)
Constant	-0.277	0.0418
	(0.252)	(0.119)
Observations	824	759
Adjusted R^2	0.141	0.128

Note: Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05

Step 2 - Results of Mediation Effects

Based on the results from Step 1, the only model that shows mediation was Model 1. Model 1 analyzed the relationships between risk factors and flood risk perceptions (severity and consequences), and the relationships between flood risk perceptions and an index of household adaptive behaviors. Based on the analyses, perceived consequences mediated several relationships. The average causal mediation effects (ACME), average direct effects (ADE), and total effects were examined using the *–mediation-* package in Stata. The *–mediation-* package provides functions of the correct calculation of the causal mediation effects using several types of parametric models while using the potential outcomes framework. The following relationships were tested for mediational effects on the combined behavioral index “index” from Model 2: InAndOut, sufferdam, knowledge, respon, and race. Table 18 reports the effects of mediational analysis of risk factors on household adaptive behaviors via perceived consequences. Table 19 reports the summary of hypotheses results.

The Effect of Ability to Get in and Out of Neighborhood on Household Adaptive Behavior via Perceived Consequences

Based on the results, experience with flooding (the ability to get in and out of a neighborhood) exerts an indirect influence on household adaptive behavior via perceived consequences resulting in an ACME of 0.009 [0.000, 0.025] at the 95% confidence level. This means that a unit increase in the ability to get in and out of one’s neighborhood due to flooding is associated with a 0.009 increase in the number of adaptive behaviors in a household. Simply put, the more a household experiences difficulty getting in and out of their neighborhood leads to heightened perceptions of their consequences associated with flooding, which then leads the household to engage in some adaptive behavior. The ADE is -0.004 [-0.094, 0.086], which is the direct relationship between a household's ability to get in and out of their neighborhood and engaging in an adaptive behavior. The total effect is 0.005 [-0.083, 0.092] which combines of the direct and indirect effects. The results of the 95% confidence interval values suggest that there is an indirect effect between the ability to get in and out of one's neighborhood and engaging in adaptive behaviors via perceived consequences, however the values for the direct and total effects include zero. All values within the confidence interval should be on the same side of zero (all positive or all negative). When the 95% confidence interval contains zero, the effect will not be significant at the 0.05 level. Therefore, we can conclude that there is a significant indirect effect, but both a nonsignificant direct effect and total effect. This reflects when that some households consider engaging in an adaptive behavior, they use both their experience and risk perceptions to engage in a behavior. However, the nonsignificant direct effect means that households do not make decisions about engaging in adaptive behavior using just their past experience.

The Effect of Suffering Damage on Household Adaptive Behavior via Perceived Consequences

Based on the results, suffering damage exerts an indirect influence on household adaptive behavior via perceived consequences resulting in an ACME of 0.028 [0.004, 0.058] at the 95% confidence level. This means that when a household experiences flooding, there was a 0.028 increase in the number of adaptive behaviors in a household. The ADE is 0.354 [0.249, 0.461], and the total effect is 0.383 [0.281, 0.486]. The results of the 95% confidence interval values suggest that there is an indirect effect between a household suffering damage due to flooding and engaging in adaptive behaviors via perceived consequences. This significant indirect means that when some households consider engaging in an adaptive behavior, they use both their experience of suffering damage to their and risk perceptions to engage in a behavior. The significant direct effect means that there is a direct relationship between a household suffering damage and engaging in an adaptive behavior. These two findings suggest that some households elect to engage in adaptive behavior without considering their perceived consequences of flooding while other households consider their perceived consequences. Overall, perceived consequences account for 8% of the total effect.

The Effect of Knowledge of Flooding on Household Adaptive Behavior via Perceived Consequences

Based on the results, a household's knowledge of flooding in relationship to sea level rise exerts an indirect influence on household adaptive behavior via perceived consequences resulting in an ACME of 0.009 [0.001, 0.020] at the 95% confidence level. This means that a unit increase in a household's knowledge regarding the relationship between flooding and sea level rise is associated with a 0.009 increase in the number of adaptive behaviors in a household. This means that when households agree that flooding is related to sea level rise, their perception of consequences become heighted, which then leads to a household to engage in some adaptive behavior. The ADE is 0.057 [-0.003, 0.119] which suggests that when a household's knowledge alone does not have a significant influence on household behavior. The total effect was 0.066 [0.006, 0.125]. The results of the 95% confidence interval values suggest that there is an indirect effect between a household's knowledge of flooding and engaging in adaptive behaviors via perceived consequences. The indirect and total effects were significant, while the direct effect was nonsignificant. Overall, perceived consequences account for 13% of the total effect.

The Effect of Locus of Responsibility on Household Adaptive Behavior via Perceived Consequences

Based on the results, locus of responsibility exerts an indirect influence on household adaptive behavior via perceived consequences resulting in an ACME of -0.007 [-0.017, -0.000]. This means that a unit decrease in a household's perceived individual responsibility to protect themselves against flooding is associated with a -0.007 decrease in the number of adaptive behaviors of a household. The ADE is -0.018 [-0.074, 0.038], and the total effect is -0.025 [-0.081, 0.030]. The results of the 95% confidence interval values suggest that there is an indirect effect between a household suffering damage due to flooding and engaging in adaptive behaviors via perceived consequences. However, the values for the direct and total effects pass through zero. Therefore, we can conclude that there is a significant indirect effect, but both a nonsignificant direct effect and total effect.

The Effect of Race on Household Adaptive Behavior via Perceived Consequences

Based on the results, the race of a household exerts an indirect influence on household adaptive behavior via perceived consequences resulting in an ACME of -0.012 [-0.029, -0.018]. This means that a unit decrease in a household's race is associated with a -0.012 decrease in the number of adaptive behaviors of a household. Non-White households have less severe perceptions regarding their personal consequences to flooding. The ADE of race on adaptive behavior is 0.115 [0.028, 0.203] which suggests that when examining the relationship between race and household adaptive behavior without risk perceptions, White households are more likely to engage in adaptive behaviors, and the total effect is 0.102 [0.016, 0.191]. Overall, perceived consequences account for 13% of the total effect. Therefore, we can conclude that there is a significant indirect, direct, and total effect of race on household adaptive behavior via perceived consequences.

Table 16. Summary of Mediation Effect Sizes

	ACME	ADE	Total Effect	% of Total Effect Mediated
InAndOut	**0.099** **[0.000, 0.025]**	-0.004 [-0.094, 0.086]	0.005 [-0.083, 0.092]	0.120 [-3.580, 2.779]
sufferdam	**0.027** **[0.004, 0.058]**	**0.354** **[0.249, 0.416]**	**0.383** **[0.281, 0.486]**	0.075 [0.059, 0.102]
knowledge	**0.009** **[0.001, 0.020]**	0.057 [-0.003, 0.119]	**0.066** **[0.006, 0.125]**	0.135 [0.066, 0.748]
respon	**-0.007** **[-0.017, -0.000]**	-0.018 [-0.074, 0.038]	-0.025 [-0.081, 0.030]	0.185 [-2.382, 2.914]
race	**-0.012** **[-0.029, -0.018]**	**0.115** **[0.028, 0.203]**	**0.102** **[0.016, 0.191]**	-0.124 [-0.528, -0.064]

Note: ACME, ADE, and total effects values are show at 95% confidence intervals in brackets. Significant values are bolded.

Table 17. Summary of Support for Hypotheses

Hypothesis	Model 1		Model 2		Model 3	
	Equation 1	Equation 2	Equation 1	Equation 2	Equation 1	Equation 2
H_{1a} - There is a direct relationship between income and household adaptive behaviors	Support	Support	-	-	Support	Support
H_{1b} - Flood risk perceptions mediate the relationship between income and household adaptive behaviors	-	-	-	-	-	-
H_{2a} - There is a direct relationship between residency tenure and household adaptive behaviors	-	-	-	-	-	-
H_{2b} - Flood risk perceptions mediate the relationship between residency tenure and household adaptive behaviors	-	-	-	-	-	-
H_{3a} - There is a direct relationship between race and household adaptive behaviors	Support	Support	Support	Support	-	-

Hypothesis	Model 1		Model 2		Model 3	
	Equation 1	Equation 2	Equation 1	Equation 2	Equation 1	Equation 2
H_{3b} - Flood risk perceptions mediate the relationship between race and household adaptive behaviors	-	Support	-	-	-	-
H_{4a} - There is a direct relationship between experience and household adaptive behaviors	Support	Support	Support	Support	Support	Support
H_{4b} - Flood risk perceptions mediate the relationship between experience and household adaptive behaviors	-	Support	-	-	-	-
H_{5a} - There is a direct relationship between proximity and household adaptive behaviors	Support	Support	Support	Support	Support	Support
H_{5b} - Flood risk perceptions mediate the relationship between proximity and household adaptive behaviors	-	-	-	-	-	-

Hypothesis	Model 1		Model 2		Model 3	
	Equation 1	Equation 2	Equation 1	Equation 2	Equation 1	Equation 2
H_{6b} - Flood risk perceptions mediate the relationship between a household's knowledge about flooding and household adaptive behaviors	-	Support	-	-	-	-
H_{7a} – There is a direct relationship between a household's perceived locus of responsibility about flooding and household adaptive behaviors	-	-	-	-	-	-
H_{7b} - Flood risk perceptions mediate the relationship between a household's perceived locus of responsibility and household adaptive behaviors	-	Support	-	-	-	-
H_8 - There is a direct relationship between flood risk perceptions and household adaptive behaviors	-	Support	-	-	-	-

Step 3 – Sensitivity Analysis

In steps 1 and 2, the key variables were identified to estimate the regression models according to the conceptual framework to test for potential mediation. The ACME and ADE were then computed according to the potential outcomes framework risk factors on household adaptive behaviors via perceived consequences. While step 2 followed the potential outcomes framework to obtain the ACME and ADE of various relationships, causality cannot be inferred due to the assumption of sequential ignorability. The fundamental difficulty of establishing mediation using observational data is the potential for confounders that may affect both the mediator and outcome variables. Here, a violation of the sequential ignorability assumption leads to a correlation between the error for the mediation model and the error for the outcome model, which is denoted by ρ that equals zero if sequential ignorability holds (Hicks & Tingley, 2012). As shown in Imai et al. (2010), the average causal mediation effect can be expressed as a function of ρ using identifiable parameters. However, researchers may find it difficult to interpret the magnitude of this correlation coefficient, and thus Imai et al. (2010) develop an alternative approach of the sensitivity analysis based on how much the omitted variable would alter the R^2 of the mediator and outcome models. If a confounder is important, then the models excluding the confounder will have a much smaller value of R^2 compared to a model including the confounder; by contrast, if the confounder is unimportant, R^2 will not be very different whether including or excluding the variable. Therefore, this relative change in R^2 can be used as a sensitivity parameter. Last but not least, the degree of sensitivity can be calibrated either in comparison to other studies (Rosenbaum & Rubin, 1983) or in conjunction with expert opinion (I. White, Carpenter, Evans, & Schroter, 2007) and there is no absolute threshold (Imai et al., 2010). Due to the lack of a base for comparison, I would simply report the sensitivity analysis results from the parameter ρ and R^2 values and be unable to assess whether the degree of sensitivity is acceptable. Therefore, I conducted a sensitivity analysis to quantify the degree to which the findings are robust to a potential violation of the sequential ignorability assumption.

The results for the sensitivity analysis indicated that the correlation for an omitted variable between the mediator and outcome would have to be 0.08 in order for the causal mediation effect to be invalidated for the following variables: ability to get in and out of a neighborhood due to flooding, suffering damage to the home, knowledge of flooding, a household's perceived locus of responsibility, and household race. Alternatively, the results of the R^2 measures of sensitivity indicate that the total variance explained by an unobserved confounder must be at least 0.07 for the mediating variable "conseq" and 0.05 for the outcome variable "index". This means that an unobserved confounder would have to explain seven percent of the variance in perceived consequences and five percent of the variance in household adaptive behaviors in order for the mediation estimates to be substantively changed. Figures 11-15 present the mediation effects with the 95 percent confidence interval at each value of ρ.

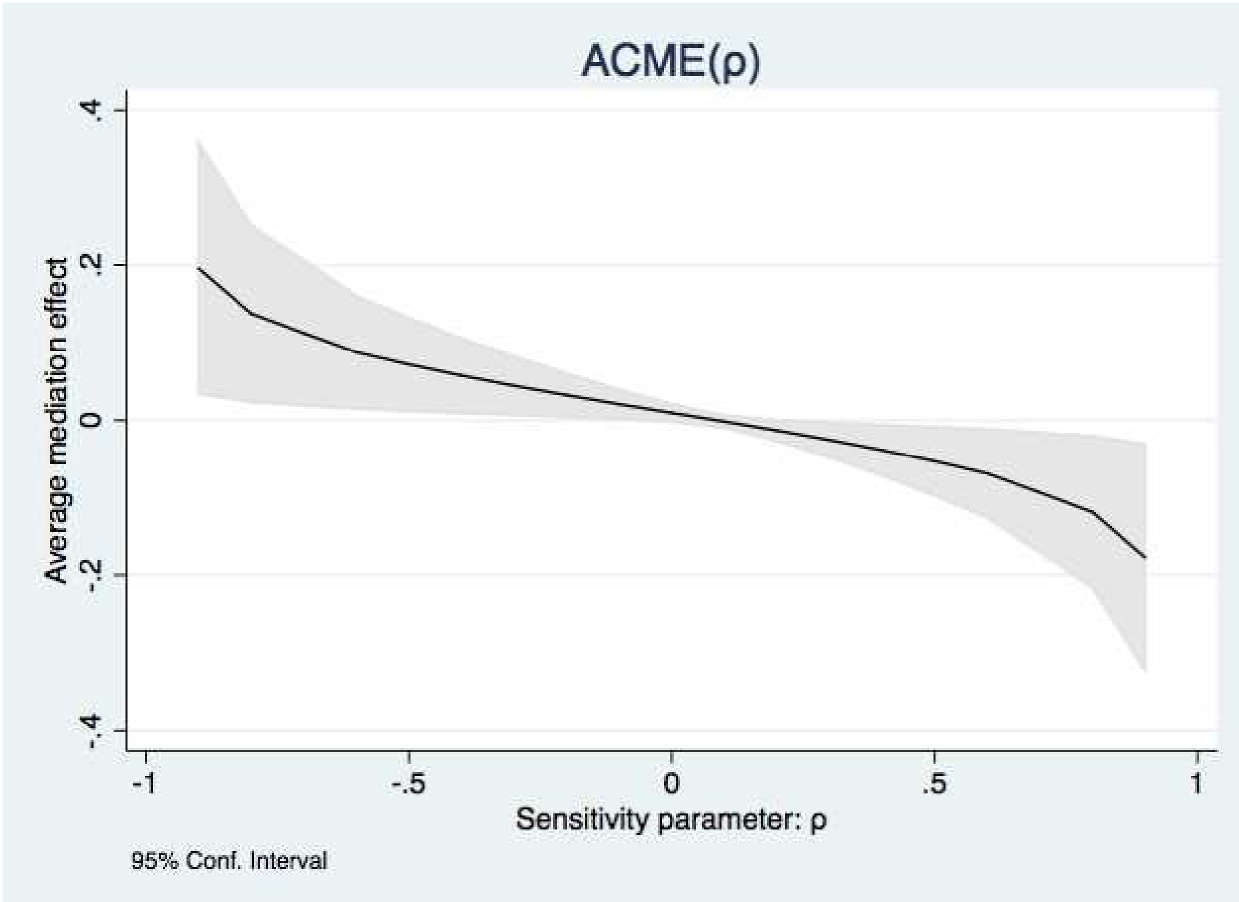


Figure 11. Sensitivity Analysis for Household's Ability to Get in and Out of Their Neighborhoods

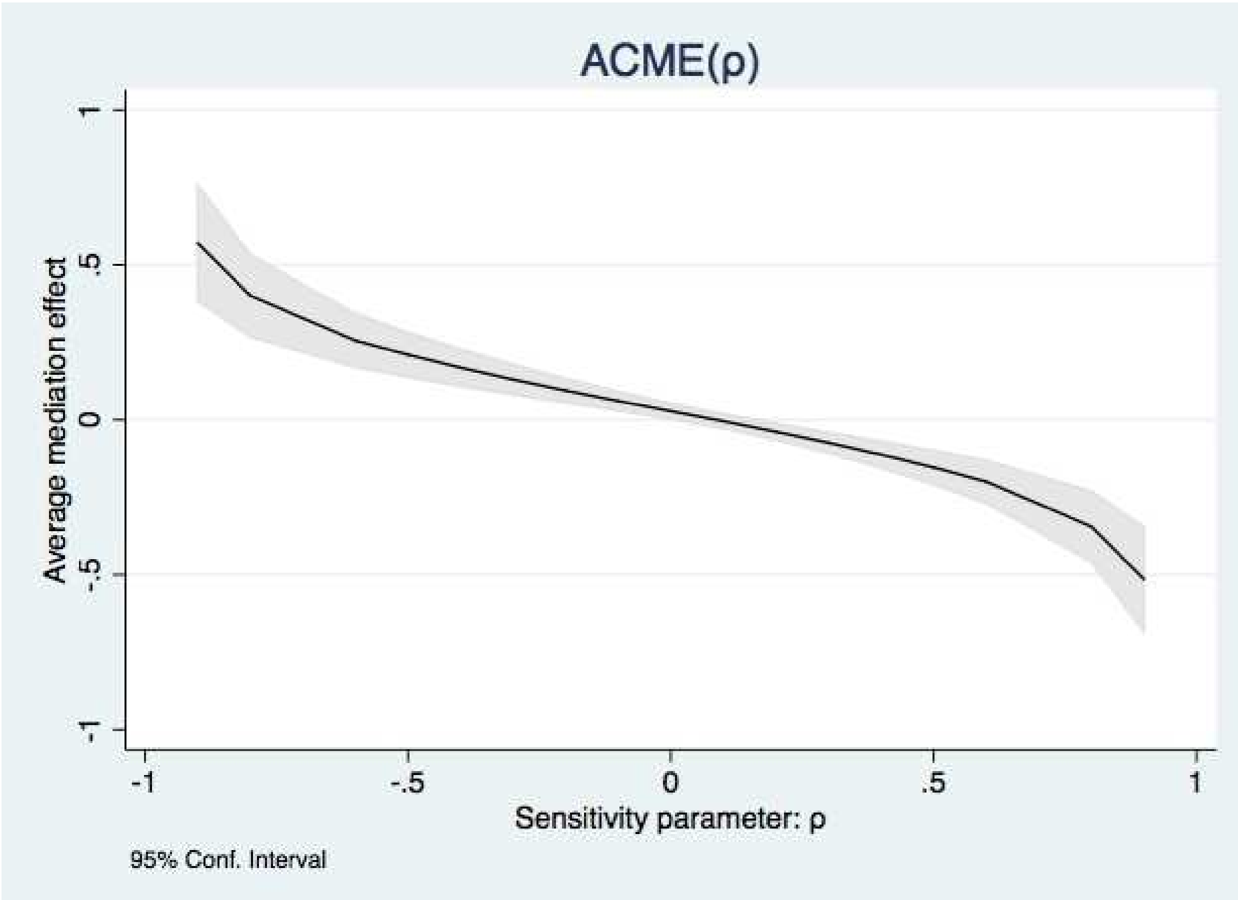


Figure 12. Sensitivity Analysis for Households that Suffer Damage due to Flooding

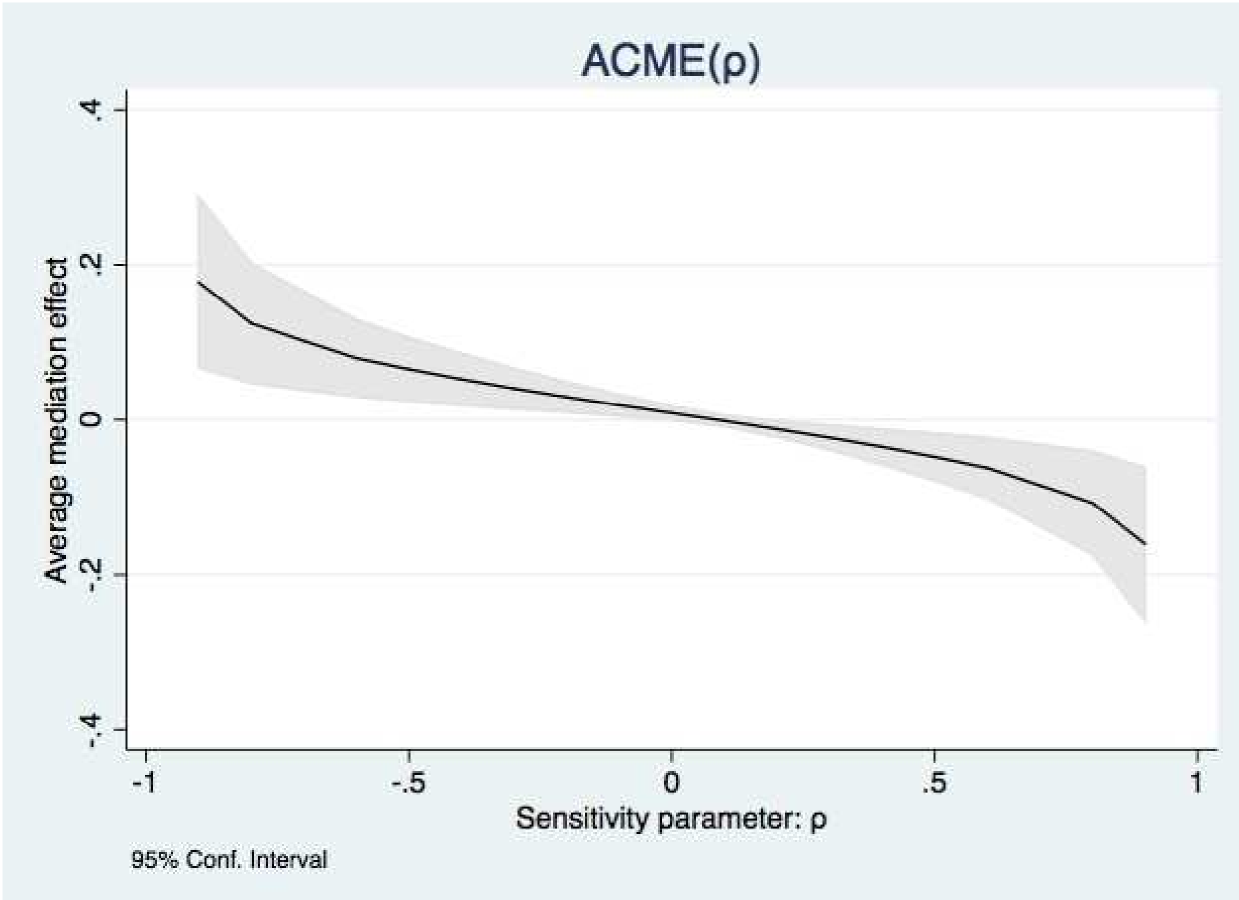


Figure 13. Sensitivity Analysis for Household's Knowledge of Flooding

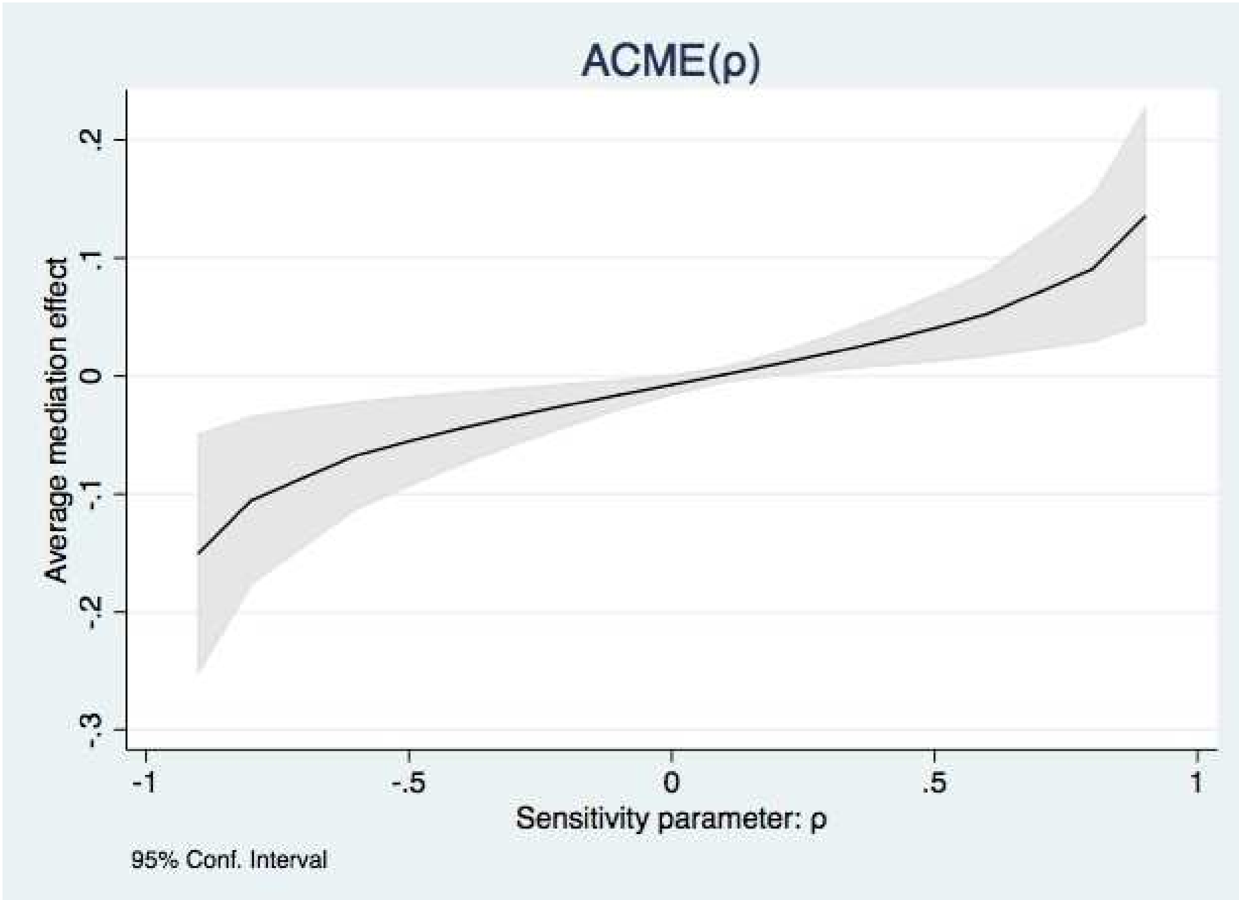


Figure 14. Sensitivity Analysis for Household's Locus of Responsibility to Flooding

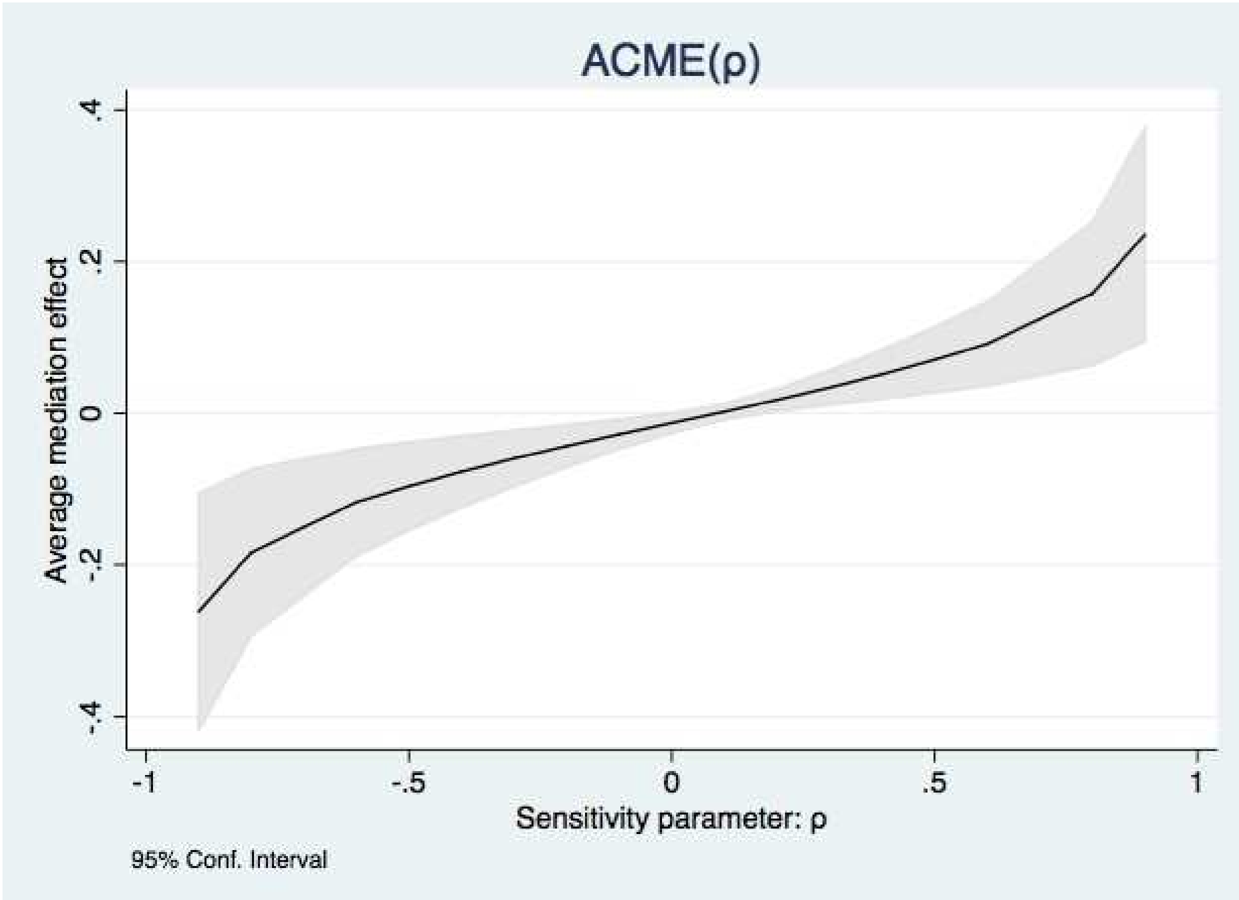


Figure 15. Sensitivity Analysis for Household's Race

This study does not test the presence of a confounding or potential omitted variable and its correlation to the mediator and outcome variables. The correlation between of a confounding or mediated variable must be 0.08 or higher to violate the assumption of sequential ignorability. To contextualize this value within this study, a review of correlation matrix was necessary to examine potential confounders in the dataset.

The following variables had a correlation of 0.08 or higher and statistically significant relationships for the mediating variable perceived consequences “conseq”: InAndOut, streetflood, sufferdam, knowledge, respon, and race. The following variables had a correlation of 0.08 or higher and statistically significant relationships for the outcome variable “index”: AEzone, meter100 meter200, InAndOut, streetflood, sufferdam, and knowledge. Within this dataset, all variables that would violate the assumption of sequential ignorability were identified in this study. We can assume that within this dataset and conceptual framework, no omitted variables are present. Therefore, the assumption of sequential ignorability was not violated.

Table 18. Correlation Matrix

Variables	AEzone	meter100	meter200	meter300	InAndOut	streetflood	sufferdam	knowledge	respon	income	tenure	race	index	cha2home	NFIP	conseq	severity
AEzone	1.000																
meter100	**0.224**	1.000															
meter200	**0.214**	**0.611**	1.000														
meter300	**0.216**	**0.463**	**0.757**	1.000													
InAndOut	0.031	**-0.075**	**-0.204**	**-0.241**	1.000												
streetflood	**0.094**	**-0.116**	**-0.236**	**-0.258**	**0.405**	1.000											
sufferdam	**0.185**	0.039	-0.015	-0.067	**0.207**	**0.256**	1.000										
knowledge	**0.035**	0.037	-0.020	-0.023	**0.102**	**0.100**	**0.091**	1.000									
respon	0.039	0.031	**0.088**	**0.116**	**-0.188**	**-0.212**	**-0.134**	**-0.117**	1.000								
income	0.020	**0.097**	**0.118**	**0.134**	-0.031	-0.021	0.035	0.018	0.008	1.000							
tenure	-0.034	**0.059**	0.062	0.028	**-0.033**	**-0.130**	0.002	**-0.064**	0.037	-0.116	1.000						
race	0.046	**0.212**	**0.286**	0.314	**-0.201**	**-0.113**	-0.064	**-0.158**	**0.156**	**0.081**	**0.125**	1.000					
index	**0.295**	**0.128**	**0.104**	0.104	**0.086**	**0.178**	**0.321**	**0.105**	-0.064	0.107	-0.027	0.078	1.000				
cha2home	**0.153**	-0.009	-0.020	-0.015	**0.092**	**0.207**	**0.321**	**0.113**	-0.074	**0.086**	-0.013	0.036	**0.703**	1.000			
NFIP	**0.282**	0.185	**0.162**	**0.157**	0.042	0.074	**0.176**	**0.051**	-0.026	**0.077**	-0.027	0.077	**0.799**	**0.133**	1.000		
conseq	0.008	0.006	**-0.060**	**-0.076**	**0.202**	**0.174**	**0.267**	**0.174**	**-0.190**	-0.043	-0.041	**-0.184**	**0.154**	**0.140**	**0.096**	1.000	
severity	0.061	0.059	0.004	-0.006	**0.136**	**0.110**	**0.081**	**0.547**	**-0.168**	0.030	-0.022	-0.072	**0.096**	**0.087**	0.060	**0.117**	1.000

6. DISCUSSION

The goal of this dissertation was to assess if various risk factors influence household adaptive behaviors via flood risk perceptions. To date, little research exists that decomposes the potential indirect and direct effects of flood risk perceptions in explaining adaptive behavior at the household level. This research provided an opportunity to advance our understanding of how risk perceptions are used in the decision-making processes for households that engage in adaptive behaviors to flooding.

The proposed conceptual framework for this study was constructed by examining the literature on the factors that flood risk perceptions, household adaptive behavior, and the theoretical considerations of the original (Rogers, 1975) and the extended (Bubeck, Botzen, & Aerts, 2012) Protection Motivation Theory frameworks which are mental models or "cognitive maps" of decision-making. While more recent developments posit that flood risk perceptions rarely explain if a household engages in risk reduction behaviors (Bubeck, Botzen, & Aerts, 2012), I argue that the role of flood risk perceptions in theoretical frameworks has failed to address and statistically examine its mediating role. The meta-analysis conducted by Bubeck et al. (2012) was comprised of 16 articles that examined the relationships between flood risk perceptions and private household mitigation. Although their theoretical discussion and analyses were robust, the limited empirical basis of their review may not justify that claim.

Risk perceptions are the result of a cognitive process in which individuals and households may employ in their decision-making processes. Households may also make decisions regarding the type of adaptive measure to engage in without considering risk perceptions. The former is reflective of a peripheral process of persuasion while the latter is a more systemic approach to decision-making. These cognitive processes are explained by Rogers

(1975) as threat and coping appraisals. These processes were further operationalized as perceived severity, perceived consequences, perceived response efficacy, perceived self-efficacy, and perceived costs. The PMT framework assumes that responses to risks are a direct multiplicative function of these five processes. The traditional approach to examining household adaptive behavior has been through single-equation regression models where a cumulative index is treated as the dependent variable, and each cognitive process is treated as independent variables. While regression analyses are sufficient to infer association, the linear regression framework is limited in inferring causality. Causal analysis goes a step further not just to infer association, but the change of the outcome variable under changing conditions. These conditions may be the independent variable or external interventions (Pearl, 2010). Additionally, previous studies that have examined household adaptive behaviors have been limited to observation data which is typically collected at one time, which limits the ability to infer causality without a temporal ordering of events.

The literature also reflects various factors influence flood risk perceptions. These factors include personal characteristics, proximity to a large body of water, and past experience with flooding. These factors precede the cognitive development of risk perceptions. According to the PMT framework, risk perceptions precede response to risk. Therefore, it may be deduced that there is a successive relationship between risk factors, flood risk perceptions, and behavioral responses. However, this successive relationship was not tested in the studies reviewed by Bubeck et al. (2012). This study addresses this current limitation.

When examined in statistical analyses, the results may underestimate the role in flood risk perceptions. This is due to the lack of a systematic approach to analyzing the effect of flood risk perceptions. Linear regression equations are primarily used to test causal relationships, assuming that an outcome variable is a multiplicative function of predictor variables. However, when the predictor variables function in a successive order, a simple linear regression fails to capture the nuanced relationship of the role of a mediating variable. In this dissertation, I argue that various household risk factors (proximity, experience, knowledge, locus of responsibility, and personal characteristics) directly influence if a household engages in adaptive behavior. I also argue that based on an extant review of the literature, mediation may exist amongst these relationships via flood risk perceptions by analyzing the hypothesized conceptual framework. The results of this study conclude that risk factors play both a direct in explaining household adaptive behaviors and indirect role via flood risk perceptions.

Summary of Results

The results of this study show that various risk factors directly influence if a household engages in adaptive behaviors. Model 1 examined the role of risk perceptions, perceived severity and, perceived consequences, on household adaptive behavior. The following hypotheses were fully supported: H_{1a}, H_{6a}, and H_{6b}. There were direct effects of income and knowledge on household adaptive behaviors, and an indirect effect of knowledge on household adaptive behaviors via perceived consequences. The following hypotheses were partially supported: H_{4a}, H_{4b}, H_{7b}, and H_{8}. Three indicator variables were analyzed to test the direct effect of experience with flooding on household adaptive behavior, streetflood, InAndOut, and sufferdam. InAndOut, which measured the whether the participant or someone in the household was (un)able to get in and out of their neighborhood due to flooding, had an indirect effect on household adaptive behavior via perceived consequences. This indicator is reflective of indirect experience as the participant may have experienced this themselves or through another member of the household. Sufferdam, which captured if the household suffered damage to their property from flooding, had both a direct and indirect influence on household adaptive behaviors via perceived consequences. This indicator was reflective of direct experience as it is assumed that all members of the household share the house dwelling. A participant's perceived level of individual responsibility to protect themselves against flooding had an indirect on household adaptive behavior via perceived consequences. Finally, of the two models, perceived consequences had a direct influence on household adaptive behavior while perceived severity did not, resulting in partial support for H_8.

Model 2 analyzed the direct and indirect effects of risk factors on if a household made a change to their home or property as a result of flooding via flood risk perceptions. Findings from both of the models reject the null hypotheses that proposed a mediating relationship between risk factors and changes made to a home. There was support for hypotheses H_{3a} and H_{6a} that proposed direct effects on a change made to a home to include race and knowledge of flooding. Support was present for H_{4a} and H_{5a} where indirect experience and living in a flood zone led to direct increases in changes made to a home. However, perceived consequences nor perceived severity nor perceived consequences were significantly associated with changes made to a home, failing to reject the null hypothesis for H_8.

Model 3 revealed that there were direct relationships between proximity, direct experience, and income on the purchase of flood insurance, thus providing support for hypotheses H_{1a} H_{4a}, and H_{5a}. However, the results fail to reject the null hypothesis for H_8 given that perceived severity nor perceived consequences were significantly related to the purchase of flood insurance.

Overall, support for hypothesis H_{1a} is consistent with several other studies that found a significant and positive relationship between household income and adaptive behaviors (Botzen et al., 2009b; Kriesel & Landry, 2004). To no surprise, the higher one's household income leads to an increase in homes that purchase flood insurance in coastal areas. This is likely that the more income a household earns, the more likely they are able to afford flood insurance. Three hundred seven respondents reported that they had purchased flood insurance for their home. Of those 307, approximately 80% of the respondents reported an average household income of more than $40,000 (n = 241) while approximately 20% reported an annual household income of less than $40,000 (n = 61). Nonetheless, we fail to reject the null hypothesis for H_{2b} because income does not influence the adoption of adaptive behaviors via flood risk perceptions across all models.

Across all models, there was no support found for a hypotheses H_{2a} and H_{2b} for the direct or indirect relationship of residency tenure and adaptive behaviors. To date, only one study has been found to test this relationship and found a marginal but non-significant relationship (Lindell & Hwang, 2008). While a household's years of residency is one approach to characterizing their home, it is still unclear if this factor is an explanatory variable or control variable across studies.

The role of race on risk perceptions and adaptive behaviors is a part of a growing conversation in the natural hazards literature. Based on the hypothesized conceptual framework, race was expected to have both a direct impact on adaptive behaviors and indirect impact via flood risk perceptions. Model 1 supported hypothesis H_{3b}, there was an indirect effect of race on adaptive behaviors via perceived consequences. In path a_2, there was a significant and negative relationship between race and perceived consequences of flooding. This means that the increase in reported non-White households led to less severe perceptions of individual consequences associated with flooding. Contrary to other studies that find that non-White populations tend to be more skeptical of natural hazards and risks (Blanchard-Boehm, 1997; Finucane et al., 2000). Without controlling for the mediator, the direct effect of race on adaptive behaviors is positive, suggesting that White households engage in adaptive behaviors more than non-White households.

Support for H_{4a} was found in Model 2. An increase in reported street flooding leads to an increase in changes made to a home or property. A plausible explanation that could be made is that that street flooding may have caused damage to one's home or have the potential to cause damage. Therefore, households have responded by making a change to their home or property. The survey asked participants to describe the type of changes made to their home. Based on the results, the responses were categorized into three types: drainage changes, additions to property, and replacements to property. None of the models found support for H_{5b}, the indirect effect of street flooding on household adaptive behaviors.

Residing in a designated flood zone was a direct predictor of household adaptive behavior across all three models. While support for H_{5a} was found, we fail to reject the null hypothesis of H_{5b}. The three indicator variables of a household's proximity to the coastline did not have a direct or indirect effect on household adaptive behaviors. This is contrary to the findings of Botzen et al. (2009a); Botzen and Van Den Bergh (2012). In this case, households in Portsmouth are not motivated to purchased flood insurance just on the basis of leaving the coastline. There are two plausible reasons. One, households that reside near the coastline may be located in designated flood zones. For homes that are insured through the federal government, purchase of flood insurance is mandatory. Therefore, these homeowners do not need additional information to decide to purchase flood insurance at a minimum. It is expected that flood risk perceptions would be irrelevant in making this decision. Second, other homeowners may accept the risks associated with living near the later. Some homeowners choose to live near bodies of water to enjoy its recreational benefits while accepting the potential hazardous risks of flooding (Wachinger et al., 2013).

Support for hypothesis H_{6a} was found in Models 1 and 2 supports for H_{6b} was found in Model 1. The connection between flooding and sea level rise, or flooding as a byproduct of sea level rise, was widely accepted amongst the households in this survey. More than the majority of the respondents reported that they agree that sea level rise and flooding are related. While the knowledge of climate change, sea level rise, land inundation, and other environmental stressors are related to the more frequent flood events in Portsmouth, this question provides insight into how households understand their vulnerability to flooding. Within the context of Hampton Roads and Portsmouth, residents' understanding of the effects of sea level rise may prompt or persuade them to engage in risk reduction behaviors.

Support for H_{7b} was found in Model 1. A household's perception of their responsibility to protect themselves against flooding led to an increase in household adaptive behaviors via perceived consequences. The paradigm shift in flood risk management calls for households to take more responsibility in mitigating their risks associated with flooding, particularly in coastal communities. Therefore, we see that the more a household accepts responsibility leads to an increase in their perceived consequences of flooding, which then leads to an increase in adaptive behaviors.

Support for H_8 was found in Model 1. Two dimensions of flood risk perceptions were analyzed, perceived consequences, and perceived severity. None of the models found support for a direct influence of a household' perception of the severity of flooding in Portsmouth to leads to a significant increase in adaptive behaviors. However, we find in Model 1 that a household's perceptions of consequences associated with flooding are directly related to an increase in adaptive behaviors. This finding is important as it adds to the discourse of the current dialogue regarding the role of flood risk perceptions in risk management. While perceived severity did significantly explain changes in a household's adaptive behaviors, perceived consequences did mediate several relationships. This means the current claim that flood risk perceptions rarely explain household adaptive behavior by Bubeck et al. (2012) and colleagues (Wachinger et al., 2013) is challenged with the evidence of this study. In part, we can conclude that perceptions of the severity of flooding do influence risk reduction behaviors at the household level. This may be attributed to the psychological distance associated with sea level rise and the recency of flood events at the household level. Given that projections of more severe sea level rise impacts are expected to gravely impact Portsmouth in the next 50 to 60 years, households may de-prioritize safety precautions due to the human nature of using short term memories (e.g., recent storms) as a point of reference in their decision making. Therefore, perceived consequences have a more immediate and imminent effect that perceived severity.

Revised Conceptual Framework

Based on the findings of this study, a revised conceptual framework was developed in Figure 16. In the revised framework, I refer to the indirect paths as peripheral routes or persuasion while the direct effects are more central routes to persuasion as applied to flood contexts (Cacioppo, Petty, Kao, & Rodriguez, 1986; Petty & Cacioppo, 1986). Within the psychology literature, Petty and Cacioppo (1986) describe a central route to persuasion as the thoughtful consideration of arguments and ideas of a message. They assume that individuals that initials that are motivated and have the ability to process messages. As applied to the conceptual framework, the central route to decision making assumes that households make choices that are dictated by their income and if they reside in a flood zone. Inherently, homeowners who choose to live in a flood zone accept that they will have to purchase flood insurance at a minimum. Others who are not required may also choose to purchase flood insurance voluntarily. The significant and positive relationships of income and proximity suggest that higher household income and living in a flood zone lead to an increase in household adaptive behaviors. For example, if the purchase of flood insurance is mandatory, perceptions of risks become irrelevant due to the mandates by federal laws. This is of particular interest as the National Flood Insurance Program is a public policy administered through the Federal Emergency Management Agency. To promote involuntary participation in the program, flood plain managers may consider how to communicate risks differently to those who have indirect or direct experience, creating awareness regarding the connection between local sea level rise and flooding, promoting self-responsibility in protecting one's household, and how messages may be tailored to different ethnic groups.

When income and proximity become irrelevant to those who may not have higher incomes or mandated to purchase flood insurance, the peripheral route of persuasion may be an alternative to promote risk reduction behaviors. The peripheral route to persuasion as described by Petty and Cacioppo (1986) consists of an individual processing messages but does not have the motivation to think about them individually. Individuals then tend to form attitudes, or perceptions, about these messages, which ultimately leads to a change in behavior. For example, an individual who lives near a large body of water may not voluntary make changes to their home or purchase flood insurance. However, messages that they receive (e.g., from family members, coworkers) of indirect experience may lead them to create perceptions about the severity of flooding, which then may lead to an increase in some adaptive behavior.

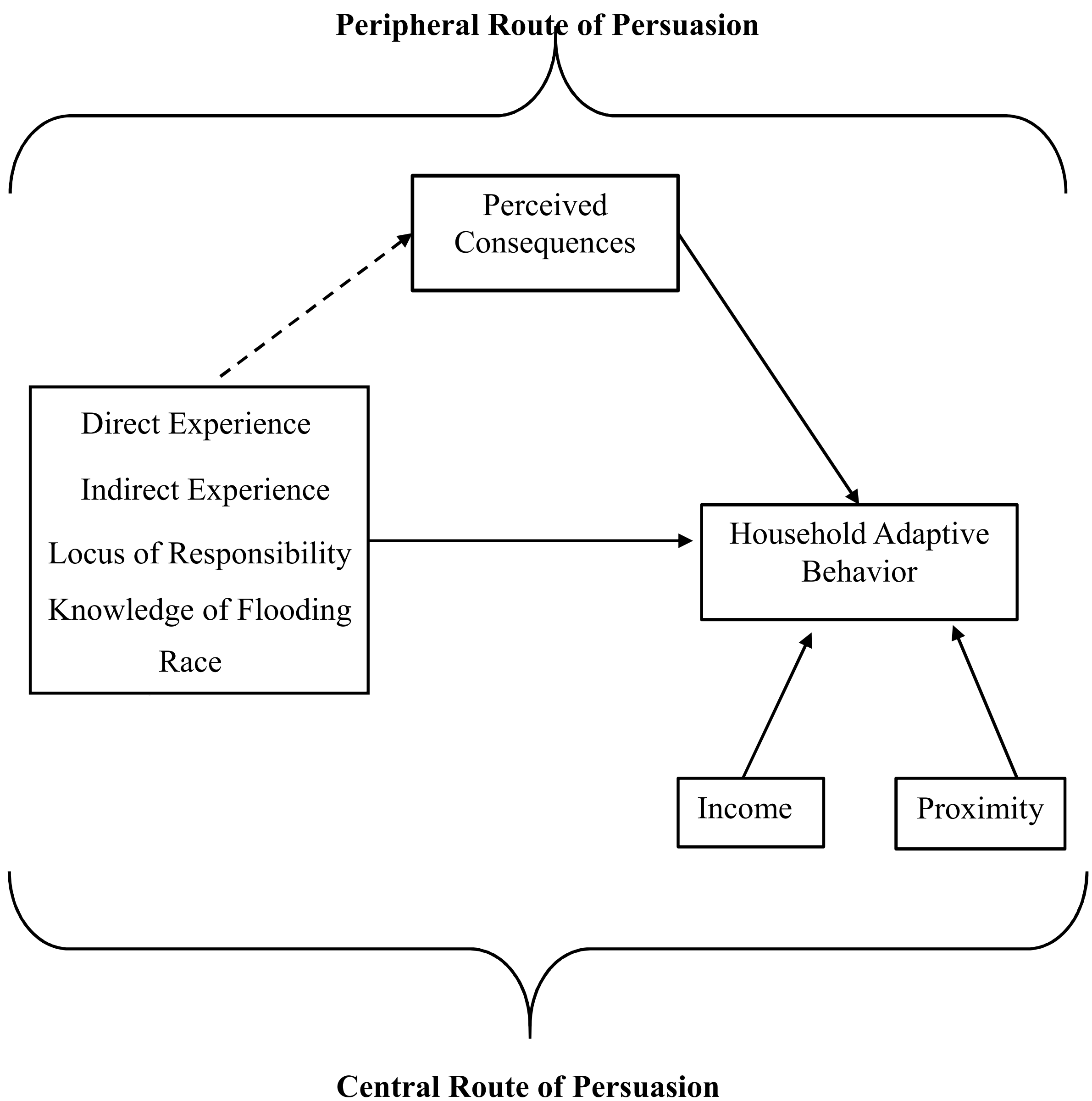


Figure 16. Revised Conceptual Framework

Note: A solid line denotes a direct relationship. A dotted line denotes a mediating relationship.

Policy Implications

Findings from this study are useful within the flood management and emergency management policy domains for the government. To contextualize the findings within flood risk management, there were several implications for public policy.

Citizen Participation, Risk Awareness, and the Community Rating System

Public participation and knowledge are critical to flood risk management. This process requires careful thought "to clarify just what it is that the parties know and believe" (Fischhoff, 1983, p. 247). City plans provide guidance for overall decision-making of the development and design of a city's infrastructure, networks, and systems. This means that the city planning process should be rooted in a democratic process where residents have a voice in its creation. The City of Portsmouth's most recent comprehensive plan was approved in 2018 and Flood Management Plan in 2015. Although these two plans provide guidance to reducing flood risks, there has historically been a deficit in the level of engagement between residents and the city in developing these policies. Efforts to increase citizen participation will have to move beyond traditional mechanisms (e.g., town hall meetings, mailings). Instead, the city may consider using social media, cellular text messages, and a variety of other methods to ensure a diverse and inclusive population is represented in city decision-making (Jacobs, 2018).

Residents are increasingly making the connection that local flooding is related to sea level rise. Therefore, the city must continue to include risk awareness as a policy in their flood management program. Portsmouth may think of applying for supplemental funding to increase their capacity to educate citizens to effectively influence risk perceptions.

Participation in the Community Rating System (CRS) is critical to the amount a household will pay for their deductible. In general, the increased participation of households that in the CRS leads to reduced premium payments for those who purchase flood insurance through the National Flood Insurance Program. To promote or increase participation in the CRS, the local flood management team may consider ways to communicate the shift in flood reduction from the government to individual households.

Building Trust and Risk Communication

Gordon and Covi (2015) surveyed local governments' staff preferences for flood communication strategies in Hampton Roads. The report found that approximately 20% of the respondents were dissatisfied with their city's outreach strategies. Council et al. (2018) surveyed the flood risk perceptions, experiences, and adaptive behaviors of low-to-moderate income families located in designated flood zones in Portsmouth. They found that more than half of the respondents did not utilize the city's current outreach strategies, which were primarily through the city's website and city planning. There is a clear gap in communication efforts, although this is to be expected. There is much difficulty in communicating risks to a multi-generational population. Therefore, cities may consider risk communication strategies that reach beyond traditional methods. For example, Council et al. (2018) recommended that the city's flood risk management team collaborate with the city's planning department to create a position that is dedicated to personal outreach. This is due to an overwhelming majority of respondents having a low level of trust amongst city employees. This position would be responsible for creating trusting relationships in more intimate settings where the receiver (resident) and communicator (city employee) may engage in bi-lateral communication.

Shifting Responsibility and Addressing Inequities

An interesting finding of this study is that a household's knowledge of flooding and a household's perceived responsibility to protect themselves against flooding influence adaptive behavior via perceived consequences. This means that the city must continue to work towards increasing awareness about flooding to residents, tying back to risk communication.

In each of the models examined in this dissertation, income was found to have a direct and positive relationship with household adaptive behavior. Currently, more than 20% of the population lives in poverty in Portsmouth (Bureau, 2013), and approximately 22% of the households in the survey data used in this study reported a median household annual income of less than $40,000. Households that earn more than $40,000 a year were constituted approximately 78% of households that have purchased flood insurance or made a change to their home. In the city's current comprehensive plan, Portsmouth is moving in the right direction by addressing poverty reduction as a priority of the city. The city has not set clear strategies to achieve this goal, and may benefit approaching this priority in a similar fashion of the city of Norfolk's Vision 2100 plan.

The empirical data from this study show that the role of race in explaining household adaptive behaviors is nuanced. The direct relationships between household ace and adaptive behavior is positive and significant. This indicates that White households engage in more adaptive behaviors compared to non-White households. The mediation analysis reveals that when taking into account a household's perceived consequences of flooding as a mediator, the relationship between race and household adaptive behavior is negative and significant.

The implications for these findings suggest that different racial groups utilize different mechanisms to make decisions about engaging in household adaptive behaviors. This means that future risk communication strategies must take into account that different racial groups use different factors to make decisions about household adaptation to flooding. Future communication strategies should consider content that emphasize how the impacts of flooding may affect their home if they do not engage in adaptive behaviors. Given that race is a social construct, there is an opportunity to further explore underlying belief systems and other cultural factors and incorporate these findings within local public policy.

Contribution of the Study

The findings from this study enhance our knowledge of how we understand a variety of mental models in flood risk management. This work contributes to the theoretical and methodological advancement by specifying key factors that explain household adaptive behaviors and the indirect role of flood risk perceptions. The revised conceptual framework attempts to model a more systematic and realistic approach to decision-making.

This study has demonstrated an initial attempt in flood risk perception and behavioral studies to infer causality amongst a successive chain of variables. Several studies have attempted inferred that mediation may be present amongst a set of relationships via risk perceptions in the natural hazards literature (Lindell & Perry, 2012; Martin et al., 2009). However, these studies have been limited in inferring causality due to the use of observational data collected at one data point, lack of randomization, and using linear equation modeling. These limitations make it difficult to establish causality amongst a set of hypothesized relationships.

The methods used for this study extends beyond inferring association to inferring causality using the potential outcomes framework and sensitivity analyses to test the assumption a potential violation of sequential ignorability. Based on the ACME and ADE effects of the potential outcomes framework, we can infer that both indirect and direct experience with flooding, knowledge of flooding, locus of responsibility, and race influence household adaptive behaviors via perceived consequences. In a successive relationship, we see that a change in risk factors leads to a change a household's levels of perception of the severity of flooding which then leads to some change in behavioral response.

The conceptual framework may also extend to other policy domains. In the emerging discipline of behavioral public policy, there is a growing interest in using social psychology and behavioral economics to understand how the public engages in public policies. This framework may be used in policy domains to understand and decompose how the public assesses a risk of interest and the factors that influence risk reduction behavior. The increased understandings of factors that influence attitudes and behaviors and ultimately behavioral responses lead to better policy creation and implementation by incorporating localized in the policy process (Jacobs, 2018).

The revised conceptual framework of this study also contributes to the knowledge of how we understand decision making regarding adaptive behavior at the household level. The original framework hypothesized that household adaptive behavior was a function of both a direct relationship and indirect direct relationship via flood risk perceptions. The analyses decompose these relationships, and are reflected in the revised framework. The revised framework provides insight into the factors that have a direct influence on adaptive behavior, and the indirect influence of perceived consequences.

Future Research

Overall, the key strengths of this study were testing the hypothesized conceptual framework using the potential outcomes framework to determine if we can infer causality based on the average causal estimated effects followed by sensitivity analyses to test the robustness of a potential violation of sequential ignorability. The results from the sensitivity analysis tell us that a confounding factor must have a 0.08 correlation between the mediation and outcome model to reverse the average causal mediation effects found in this study. No confounding factors were tested in this study as the key variables that influence household adaptive behaviors were identified in the models. However, there always exists the potential for an unknown confounder to affect both the mediator and outcome variable. Future studies may test the presence of a potential confounding variable to see if it indeed reverses the ACME value to zero. Due to the limitations of the observational data set, panel data will be more appropriate in establishing causal as suggested by Bubeck et al. (2012).

The revised conceptual framework is a step in the right direction of developing a more systematic and comprehensive understanding of how households make decisions to reduce their risks to flooding in coastal communities. Future studies may use this model as a guide for developing a research design and testing the validity of the model. Future efforts to test the conceptual framework from this dissertation should use panel data to establish causal relationships.

Risk perceptions are often influenced by communication messages. Future studies should consider testing various types of messages to communicate flood risks, and determine which types of messages are received by the residents of Portsmouth that may influence their motivation to engage in adaptive behaviors to flooding.

Limitations

There are some limitations to this study. First, since the study only considered households in Portsmouth, Virginia, the results cannot be generalized to other coastal communities. Second, the data used in this study are secondary. Therefore, the potential for human error in data input and entry in creating the dataset may be present. Third, the data are self-reported. Self-reported data may contain measurement error or bias. Fourth, given that the dataset only observed adaptive behaviors that are typical to homeowners, the analyses were limited to households that own their own. Renters were not included in the analyses.

Second, the usage of observational data creates difficulties in establishing or inferring causality. However, the data were analyzed using the potential outcomes framework and testing for a potential violation of the sequential ignorability assumption.

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