Differential residential perspectives on *in situ* protection and retreat as strategies for climate adaptation

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1. Introduction

Coastal communities are uniquely vulnerable to damage and disruption due to climate change (Behr et al. 2016). Increased damage is predicted to occur due to sea level rise (SLR) and greater storm severity (IPCC 2012, 2018). Taken together, these environmental changes will interrupt existing settlements and livelihoods, destroy infrastructure, and make previously-productive agricultural areas untenable (IPCC 2015). Without aggressive adaption measures, these changes are predicted to lead to the displacement of hundreds of millions of residents, worldwide (Wong et al. 2014; Brown 2008).

Deteriorating environmental conditions drive the necessity of adaptation; however, little is known about why individual households prioritize different strategies towards protective actions (Hunter, Luna, and Norton 2015; Babcicky and Seebauer 2018). A growing body of literature (Bardsley and Hugo 2010; McLeman 2011; Piggott-McKellar et al. 2019) demonstrates that residents face these growing environmental issues in a number of ways; such as by employing *in situ* adaptive approaches to mitigate the threat, or participating in migration to leave the area under threat. For the scope of this paper, we will refer to the latter phenomenon as 'retreat,' a term defined here as permanently moving away from one's home in hazardous areas due to adverse conditions. We use the term retreat based on its association in coastal management strategy implemented in many domestic rural and agricultural areas (Koslov 2016).

The broad goal of this paper is to understand how individuals perceive the relationship of *in situ* protection and retreat as adaptation measures, and the factors driving them. Specifically, we pose three questions: (1) What is the relationship between residents' exposure to disasters and adverse environmental conditions, perceptions of climate trends, and fears about the future? (2) How do these factors influence openness to different adaption strategies? (3) Are these strategies considered to be *progressive* – where protection is indexed to lower levels of threat and retreat occurs when those measures fail – or are these dichotomous strategies? That is, do residents consider incremental *in situ* adaption approaches to counter a rising threat, and retreat as a last resort when those protections fail? Or, do residents prioritize either protection or retreat as exclusive options? We hypothesize that, whether or not different adaptation strategies tend to occur progressively *over the long term*, they are not *perceived* as progressive strategies in the short term. Rather, residents will either have an interest in sinking costs into place to protect their existing home, or they will want to migrate away before accruing significant expenditures or losses.

In order to address these questions, we analyze responses (*n=147*) to a residential drop-off/pick-up survey conducted across the Albemarle-Pamlico Peninsula in the State of North Carolina (USA). This survey collected data about residents' properties, communities, and beliefs, as well as their experiences with saltwater intrusion and flooding, their perceptions about storm events, and their behaviors relevant to managing them. Select responses are analyzed using both risk perception literature (Bubeck, Botzen, and Aerts 2012; Aerts et al. 2018) and environmental adaptation and migration literature (Adger 2009; McLeman 2017) as theoretical frameworks. Using a structural equation model (Hoyle 1995; Bollen and Long 1993; Kline 2005; Bowen and Guo 2012), we examine the factors that drive residents' willingness to engage in *in situ* adaptation to protect their property and homes, or to leave their property outright.

Our results show that residents who are concerned about future trends are more open to moving away from their community. We find that an optimistic perception of flooding over the past two decades (i.e. flooding has gotten better, storms have gotten milder, etc.) is associated with reluctance to engage in protective measures generally. We also found that a resident's pessimistic perception of past events, *absent of* concerns about the future, is correlated with a greater openness for *in situ* adaptation measures. Our results have implications for efforts to build local capacity for resilience by providing community leaders with insight into how individuals frame decisions around climate and environmental adaptation strategies.

2. Background

2.1 *Adaptation to Sea Level Rise and Worsening Floods*

In the context of climate change, "mitigation" traditionally refers to actions taken to reduce (or, ideally, reverse) the progression of climate change; whereas "adaption" refers to developing strategies for preparing for imminent changes to reduce exposure and vulnerability. In the hazards field, disaster and hazard adaptation is often further divided into "structural measures" and "nonstructural measures". Structural adaptation measures include engineered solutions, like levees, sea walls, and canals (IPCC 1990). Nonstructural adaptation measures include land-use regulations that prevent development in at-risk areas, insurance, communication plans for to warn residents of local hazards, evacuation plans, etc. (Perry et al. 2007).

Historically, flood mitigation practices have focused heavily on structural solutions, but, increasingly, they are trending towards a more integrated approach. This approach focuses on both reducing the potential damage of floods (such as through levee protection or accommodating floods via home elevation; Frankhauser 1995); and transferring the risk (such as through the purchase of insurance; see, for example: Kunreuther 1996, 2015). Within this trend and in the context of climate change, "retreat" has recently gained attention as a hazard mitigation technique (Salvesen et al. 2018).

Engaging in any form of adaptation, however, requires an awareness of risk. While it is commonly assumed that increased risk perception will invariably lead to an increase in adaptive measures, this causal linkage is rarely direct, and is sometimes fully obscured. This has been addressed by disaster scholars using the Protection Motivation Theory (PMT; see, for example: Bubeck, Botzen, and Aerts 2012) and other related theoretical frames (see, for example the related Protective Action Decision Model, PADM, theory: Lindell and Perry 2012).

2.2 PMT in the context of Risk Perception and Flood Mitigation Behaviors

The field of risk perception focuses on the distinction between the risk of a situation as measured in a professional capacity, and the risk of a situation as understood by a layperson subjected to that risk. This can be clarified as the distinction between the 'real risk', or the statistical chance of harm from the hazard, as compared to a person or population's *interpretation* of the hazard and its risk (Sullivan-Wiley and Short Gianotti 2017), which is often colored by how dreaded the potential outcome is (Slovic 1987). Risk perception literature has been applied to environmental and hazard adaptation through the PMT (see, for example: Bubeck et al. 2018; Haer et al. 2017; Grothmann and Patt 2005). PMT holds that protective and non-protective responses to threats depends on both a "threat appraisal" and a "coping appraisal" (Rogers and Prentice-Dunn 1997; Rogers 1975).

Threat appraisal accounts for how individuals perceive their vulnerability to (and the potential severity of) a hazard. Once an individual acknowledges a risk, they must feel empowered to act upon it in order to achieve a protective response (Lindell and Perry 2012). This coping appraisal is composed of "response efficacy", "self-efficacy" and "response costs", which infers the ability of protective measures to mitigate the risk, the perceived personal ability of the individual to enact the protective measures successfully, and the costs that enacting the measures would entail. That is to say, even if an individual recognizes a risk, if they perceive that available adaption strategies are futile or beyond their means, they will fail to implement them.

Together, an individual's threat appraisal and coping appraisal either results in protective measures, or results in non-action (i.e., a non-protective response; Bubeck, Botzen, and Aerts 2012). In grouping the outcomes in this way, the literature views protective measures in a generalized manner, with relatively few studies focusing on explicating the impetus for engaging in differing strategies under this broad umbrella. One exception is an article by Bubeck et. al. (2012), which looked at four different types of flood coping behavior and noted that openness to them was predicated on different interpretations of risk and coping ability.

2.3 Conceptual and Real Thresholds in Climate Change Adaptation

While individuals and households have different responses and timelines to taking proactive protective measures, there are points where residents no longer have the freedom on whether or not to engage in adaptation. These points occur at threshold conditions where previous methods for sustaining livelihood and living conditions are no longer feasible, and individuals and households are ‘forced’ into taking adaptive measures. This is becoming increasingly pertinent under existing and projected disaster conditions associated with climate change, where many pre-existing settlements are facing more severe and more frequent hazard events. In this context, Adger et. al. (2009, 6) notes that:

> “There are many thresholds for adaptive action, and they generally fall into two categories. First, there are the levels or points when responses come into effect and reduce vulnerability to the negative effects of climate change. Second, there are thresholds beyond which adaptive actions cease to be effective in reducing vulnerability. These can, in effect, be considered limits to adaption, in that adaption no longer represents a successful response to climate change.”

Expanding on this concept, McLeman (2017) hypothesizes a framework for explaining individual adaptation strategies (Figure 1A). This framework explains two states of adaptation, each with three different decision stages, which progress in relation to the increasing severity of climate hazards. As threat increases over time, adaption goes from being unnecessary, to necessary for accommodate existing livelihoods, to being unable to protect existing livelihoods. This can necessitate a shift towards more robust livelihood choices. As threat increases further, the degradation becomes such that the land is no longer suitable for uses that can sustain original or alternative livelihood choices, even with intensive adaptation methods. At this point *in situ* adaption has failed and residents reach the fourth threshold: migration replaces *in situ* adaptation (McLeman 2017).

[Insert Figure 1 about here]

While this framework provides a compelling model for progressive human behavior in a hypothesized system, it does not attempt to incorporate individual perspectives that may affect the timeline of adaptation or the preferences for different adaptation strategies. Rather, these steps are implicitly perceived as linear adaptive strategies, a framework which has seen increasing utilization (see for example: Moser and Ekstrom 2010; Pelling 2012; Bardsley and Hugo 2010). However, other literature considers protection and retreat as two dichotomous outcomes. Black et. al. (Figure 1B; 2011) build an alternative framework on more traditional theories of migration (Hunter, Luna, and Norton 2015; Castles 2003; Brettell and Hollifield 2015). To do this, Black et al. augment well-established interrelationships between environmental, demographic, social, and economic migration drivers, adding the influence of environmental change as processed through a lens of household and societal factors, to determine a singular, dichotomous decision to either remain or to migrate (retreat).

In the context of these alternative theories of the adaptation decision processes, we examine how individuals perceive adaption outcomes, and whether there is variation in how they process previous experiences, perceived risks, and future concerns. This follows emerging research on the importance of evaluating the interrelationships between vulnerability and risk assessment as they relate to discrete outcomes (Babcicky and Seebauer 2018; Bubeck, Botzen, and Aerts 2012). This analysis supports a more nuanced understanding of how at-risk individuals weigh different adaptation options and the factors that influence these perspectives.

3. Study area and data

3.1 Study area

Our study area covers the State of North Carolina's (USA) Albemarle-Pamlico Peninsula (APP; Figure 2), a low relief, low-elevation peninsula. North Carolina's rural coastline offers a dramatized case study of climate change vulnerability and is a potential harbinger of early adaptation patterns (Bhattachan, Jurjonas, et al. 2018; Jurjonas and Seekamp 2018). This is due to its natural vulnerabilities and early exposure to adverse impacts of climate change. North Carolina is affected by more tropical cyclones and major hurricanes than almost any other state in the nation (NOAA 2019; North Carolina Climate Office 2019). It is also experiencing accelerated SLR and the negative impacts of saltwater intrusion (Kopp et al. 2015). Already, residents are being faced with the decisions on how to adjust to worsening conditions.

[Insert Figure 2 about here]

Just under half of the APP region is less than 1 m above average sea level, creating chronic risk of significant flooding and saltwater intrusion (Bhattachan, Emanuel, et al. 2018). Projections of 0.24 – 1.32 m of relative SLR along the North Carolina coast predict that large portions of the area will be fully inundated within this century (Kopp et al. 2015).

3.1 Survey data collection

To select household survey participants, we used a random, address-based sample (based on the US Postal Service's Computerized Delivery Sequence File; obtained from Survey Sampling, Inc. [now Dynata, Inc.]), stratified by block-group to ensure complete spatial coverage of the APP. This survey instrument contained 126 questions (~30 minute completion time, per pre-testing), including questions about respondents' property, disaster and flooding exposure, community relationships, climate-related concerns and fears, and their openness to different future plans.

We developed questions for this survey instrument in coordination with an advisory group consisting of professionals from NGO's and scholars experienced with this specific region and its population. This included: Christine Avenarius (Eastern Carolina University, ECU), Christine Pickens (The Nature Conservancy, TNC), and Jess Whitehead (who was with the North Carolina State University, NCSU, Extension program at the time of her involvement, and who is now head of The North Carolina Office of Recovery and Resiliency, NCORR). Due to the size of the population (with just a little over 42,300 households), and the time frame that was targeted for deploying the survey, we felt that this was an appropriate strategy for identifying survey questions.

After pre-testing the survey using cognitive interviewing with potential participants (January 2017; *n=22 residents*), we administered the survey to residents (*n=789*; 70 un-replaced refusals) using a drop-off/pick-up protocol, in which potential respondent households were physically visited up to three times (on different days/times of the week). During these visits, interviewers endeavored to explain the intent and use of the survey, and distribute the survey instrument and a $5 gift card incentive (Church 1993; per the Tailored Design Method; Dillman, Smyth, and Christian 2008). If efforts to meet respondents were unsuccessful, survey staff left the survey materials at the residence along with a business reply envelope. Three attempts were also made to pick up the surveys 1-2 weeks later, and reminder letters and return envelopes were left at homes where in-person contact could not be made. Final reminders were also mailed to non-respondents two months after survey distribution.

Of the 789 surveys given to residents, *227* were returned, yielding a final a response rate of 31.6 percent. However, not all surveys were completed in their entirety; for the questions that we analyzed, there were n=147 complete responses that answered all questions (a *completion* rate of 64.8%). With this sample size and a reference population of just over 42,300 households (ACS 2016), the chance for an Alpha error is 6.77% with a 90% confidence interval, and 8.07% with a 95% confidence interval, based on Cochran's formula (Bartlett, Kotrlik, and Higgins 2001). Based on this, it is possible that the results show an Alpha error that finds differences that do not actually exist within a given population. However, we feel that we have taken reasonable measures to produce a high response rate based on the detailed level of survey instrument implement. While future studies will be needed to confirm our findings and increase validity in general applicability beyond the APP (Bartlett, Kotrlik, and Higgins 2001), these are reasonable response rates and error rates given the sensitive and detailed nature of our survey instrument.

4. Analysis Methods

Our analysis is designed to determine the relationship between residents' exposure, perceptions of climate trends, and fears about the future, as well as whether these factors influence their attitudes and openness to different adaption strategies. Moreover, we seek to determine if these strategies are considered to be *progressive* (i.e., retreat being an option after protection has been tried), or whether protection and retreat are effectively treated as discrete options chosen by distinct groups of people.

4.1 Structural equation modeling

A wide variety of studies of individual climate adaptation measures have used regression models to understand adaptation household behavior, including acceptance of floodplain buyouts (Binder, Baker, and Barile 2015; de Vries and Fraser 2012; Kick et al. 2011), purchasing flood insurance (Lo 2013; Botzen and van den Bergh 2012; Haer et al. 2017; Bubeck et al. 2012), emergency preparedness (Onuma, Shin, and Managi 2017; Zaalberg et al. 2009), and flood mitigation activities (Haer et al. 2017; Bubeck, Botzen, and Aerts 2012; Bubeck et al. 2013; Poussin, Botzen, and Aerts 2014). However, regression analysis typically prioritizes the exploration of a single dependent variable (i.e., behavioral outcome) at a time in a given analysis. Regression analysis also only focuses on the relationship between *measured* independent variables. In our case, we seek to compare multiple outcomes (i.e., retreat and protective measures), and to understand relationships between "latent" variables, which are unmeasured (or sometimes unmeasurable) facets for adaptation decision-making (Kline 2005; Bowen and Guo 2012).

To accomplish this, we use Structural Equation Modeling (SEM), a technique that facilitates latent variable analysis (i.e., unmeasured, inferred variables), as well as the simultaneous exploration of multiple dependent variables and their relationships to independent variables. While several studies have employed SEM to climate adaptation topics (Lo 2013; Kaiser, Wölfing, and Fuhrer 1999; Zaalberg et al. 2009; Watkins, Aitken, and Mather 2016; Kick et al. 2011; Babcicky and Seebauer 2018), very few have employed it to compare multiple adaptation strategies.

In our SEM analysis, we report both standardized and unstandardized coefficients. Standardized coefficients involve an analysis based on standardized effects of the data, which are then less affected by differing units of measurements. This allows for a relatively easy comparison of the importance of different variables *within* a given model. While standardized coefficients can also be used for analysis *across* models, there is a greater benefit to using unstandardized results for this aspect of the analysis. This is because they are not as reliant on equal variances across different samples or populations (Kwan and Chan 2011; Grace and Bollen 2005).

In this study, we use SEM to develop the latent variables necessary to better understand the complex relationships between resident exposure, perception of past trends, concerns about the future, and the adaptive preferences of APP residents. Figure 3 shows these hypothesized relationships between these variables, with three layers to our SEM analysis. First, we have a series of measured variables that were selected to help define the latent variables. Second, we have three latent variables, which we construct in order to better understand the features of respondents' perspectives on risks and concerns associated with living in a vulnerable community. Third, and finally, we have outcome variables that measure the respondent's reported willingness or reticence to engage in adaptive strategies.

[Insert Figure 3 about here]

According to Kline (2005), our sample size (*n=147*) is considered to be a medium sized population for SEM models (which includes a range of 100-200 observations). Considering our sample size, we utilized a case-to-parameter ratio of 10:1, and included 14 explanatory variables used to define the 3 latent variables. Because of this, we should note that socio-economic variables (i.e., age, race, gender, and education) in this analysis were largely excluded due to 1) sample size-related limitations on the number of independent variables that could be reasonably included in the equation, and 2) the limited relationships between socio-economic variables and outcomes, which are likely the result of low racial and age diversity in both the study area and dataset. For example, 63.3% of respondents are over 60 and 83.5% are white.

Demonstrating the limited impact of socio-economic data in this analysis, the socio-economic data that we collected are broken down in Supplemental Material Table 1 in a correlation matrix. As is shown in this table, the only variable that has any consistency in its impact is age, which is positively correlated with non-protective responses, negatively correlated with protection, and insignificant when compared with retreat. However, because there are inconsistencies in the literature on of the effect of age, we did not feel it had a strong added value compared to other variables (e.g., in their review of risk perception and flood mitigation behavior, Bubeck et. al. [2012] found seven studies that included age as a variable, of which most found no significant relationships).

4.2 Latent Variable Development

Latent variables are measured through correlations or covariances between observed variables with the intention of inferring a non-measured phenomenon (Bowen and Guo 2012; Kline 2005). We used observed variables to help define latent variables (Table 1) describing 1) residents' current hazard exposure levels ("Exposure"), as defined by self-reported experiences of past events, 2) perceptions of past storms and flooding (“Past Perception”), and 3) concerns about future property value and adverse community changes (“Future Concern”).

[Insert Table 1 here]

We constructed the “Exposure” latent variable by agglomerating variables indicating previous experience of flood-related hazard and nuisance conditions, lending insights into the degree of vulnerability that a resident may have been subjected to historically. We realize that there is not a perfect relationship between exposure and vulnerability (as vulnerability may not be realized). However, if we assert that participants have been subjected to similar, overall hazard conditions across our relatively small geographic study area, creating this link offers insight into the differences in effective vulnerability.

The “Past Perception” latent variable was constructed from survey questions asking residents to report their understanding of how flood-related hazards have changed over the last 20 years, both broadly and within their community. This latent variable was developed to gain insight into how the residents perceive historic trends towards either worsening or improving conditions (higher values indicate views that flooding and storms have become more severe in the last two decades; refer to Table 1). The nuance between Past Perception and Exposure relates to the tensions between risk perception and actual risk as noted in Section 2.2, with an emphasis on the relationship between threat appraisal of risk as it relates to behavioral change.

Finally, the third latent variable, “Future Concern” was constructed to indicate participants’ fears about how future storms and continued environmental degradation will negatively impact their property or community. The explicit separation of this latent variable from the previous one was designed to offer more nuanced analysis that distinguishes participants' emerging feelings of vulnerability to better understand the features that help to drive, or discourage, protective responses.

4.3 Selection of Measured Outcome Variables

Outcome variables (Table 2) were selected for their representation of resident's willingness to engage in different protective responses, based on the resident's self-reported responses.

[Insert Table 2 about here]

Our survey recorded preferences for three different adaptive response outcome (dependent) variables. The first response, "Retreat," relates to a respondent's willingness to migrate in response to flooding. This binary response is derived from the survey question: *Could you foresee that flooding would ever force you to move from your property?* The context of this question implies a long-term or permanent migration, rather than a temporary displacement as may occur in anticipation or in direct response to a hazard event. See details on survey instrument questions in the supplemental material.

The second and third responses, "*In Situ* Protection (Buildings)" and "*In Situ* Protection (Property)" refers to a respondent's willingness to install water control structures (WCS) to protect the buildings on their property from flooding and their land from flooding, respectfully. For the 'Buildings' variable, respondents were asked to, "*Imagine there is flooding on your property and <u>it is severe enough to damage building or structures</u>.*" For the 'Property' variable, respondents were asked to, "*Imagine there is flooding on your property and <u>it is **not** severe enough to damage building or structures</u>.*" For both scenarios, they were asked to respond to the question: *How frequent would this flooding need to be in order to prompt you to install or upgrade water control structures?* Single selection responses ranged from *once every six months* to *once every 10 or more years*, as well as "*I would never install water control structures*." Answers were recoded as binary, with those indicating they would never install WCS as zero, and all others as one (refer to Table 2).

Hypothetical questions are not without their limitations, and have biases because they ask for predications about an inherently uncertain future (Groves et al. 2009). This question choice reflects to better understand reactions to climate change conditions that are anticipated, but are not yet widely accepted (Weber 2006), with the intention of gauging openness to different strategies, which can be instrumental for future action (Armitage and Conner 2001). We have tried to account for weaknesses with pre-testing, described in the previous section, as well as using situations that mirror real world experiences (McDonald 2020), with familiar conditions (Iarossi 2006). While further research is required to understand how residents will respond to deteriorating environmental conditions, we feel this question provides insight into the residents' perceived willingness to engage in actions as captured at a point in time.

In our survey instrument, "water control structures" were defined as 'structures on your property that prevent or limit freshwater or saltwater flooding' and includes examples such as levees, canals, pump stations, culverts, tile drains, flashboard risers, elevating the home, and bulkheads or retaining walls. The term 'water control structures' was selected because of its applicability to the context of the area; these are the tools that both individuals and the community at large commonly used for the protection of one's property in this region according to previous studies in this area (e.g. Bhattachan, Jurjonas, et al. 2018). Water control structures do not include non-structural adaptation measures, such as having emergency kits or plans, but is defined to run the gamut of potential structural responses.

Because these scenarios were similar (refer to Table 3, showing a high correlation between "*In Situ* Protection (Buildings)" and "*In Situ* Protection (Property)" at r=0.858; p<0.01), it was not possible or useful to include both in the same SEM model. Rather, two similar models, Model 1 and Model 2, were used to explore both variations of this *In Situ* Protection response as well as to the Retreat outcome.

Retreat and *In Situ* Protection responses were not treated as mutually exclusive in the survey, and some respondents indicating a willingness to engage in more than one adaptation activity. However, respondents who indicated unwillingness to engage in either response, were designated as taking a "Non-Protective Response" strategy. This includes individuals who would never install water control structures, no matter how frequent destructive flooding might get; nor could they see flooding forcing them to move regardless of increasing intensity or frequency. The variables that led to this response was considered in Model 3, to better understand the mindset that may make individuals unwilling to engage in adaptive strategies more generally.

Taken together, these response variables are reflective of some of the inflection points defined in McLeman's (2017) and Adger et. al.'s (2009) hypothesized framework for climate change adaptation thresholds. In McLeman's (2017) analysis, the major thresholds were established at inflection points between states where adaptation is not necessary, 1) adaptation becomes necessary to protect existing livelihoods, 2) adaptation is no longer effective at protecting existing livelihoods, 3) the point where an alternative land use must be implemented, and, finally, 4) *in situ* adaption fails and the residents must migrate (retreat) to other areas capable of sustaining livelihoods. This lens implies that individuals and households will progress through these thresholds in a linear fashion, successively attempting the least aggressive strategies that are successful before finally abandoning their protective efforts altogether and retreating.

Our response variables reflect speculative (that is, anticipating future problems) responses to the first threshold (where adaption becomes necessary; "*In Situ* Adaptation [Property]"), the third threshold (where land use or livelihoods undergo fundamental change; "*In Situ* Adaptation [Buildings]"), and the fourth threshold (where in situ adaptation is replaced by migration responses; "Retreat"; McLeman 2017). However, our response set does not explicitly consider the second threshold, where adaption ceases to be effective. It also does not consider what McLeman (2017) has identified as a fifth and sixth threshold ('migration becomes non-linear', and 'non-linear migration ceases', respectfully), which considers trends beyond the scope of this study. Therefore, while this SEM does not cover the full scope of this theoretical framework, it is sufficient for understanding whether or not these decisions are perceived as progressive or dichotomous.

5. Results

5.1 Descriptive statistics

We begin by reviewing the relationships between the different adaptive responses (outcomes; Table 3). We can first see in Table 3 that Retreat has a very limited relationship to both *In Situ*

Protection measures for buildings (*r= 0.087; p>0.1, non-significant)* and property (*r=-0.015; p>0.1, non-significant*). We found strong correlations in participants' willingness to take *In Situ* Protection measures for buildings and property (*r=0.858; p<0.01);* thereby leading us to evaluate these outcomes through separate SEM models.

[Insert Table 3 here]

5.2 Standardized SEM Results

One of the clearest methods for interpreting SEM results is to analyze them in diagrammatic form, which demonstrates the relationships between different variables (see Figure 4). The coefficients reflect the effects of the independent variable on the dependent variable in relationships throughout a given path, with the direction of effect represented by an arrow; significance values are provided. Additionally, a detailed breakdown of the values is provided in the supplemental materials tables S2-4, with both the estimated coefficients and their significance levels.

Using standardized SEMs to understand within-model patterns (e.g., different relationships within a model), we can see in Model 1 (Figure 4; Supplemental Table 2) that there is a linear relationship between the Exposure and Past Perception latent variables (*b=0.43 p<0.01*), indicating that increased exposure to past events is associated with perceptions that storm severity and frequency has increased in the past. Similarly, the Past Perception variable has a positive relationship on Future Concern (*b=0.52; p<0.01*). However, Exposure itself does not have a direct, significant relationship with Future Concern. These relationships are mirrored in Models 2 and 3, figure 4.

[Insert Figure 4 about here]

In Model 1 (Figure 4) we look at Retreat and the *In Situ* Protection (Property) strategy, which involves the protection of the property (land) itself, rather than the buildings on the property. Past Perception has a positive relationship with *In Situ* Adaption ($b = 0.76$; $p<0.05$), while Future Concern continues to be positively related to Retreat ($b = 0.28$; $p<0.1$). Additionally, Future Concern has a significant negative relationship with *In Situ* Adaptation to protect property ($b = -0.63$; $p<0.05$). The chi-square test of model fit indicates an improvement upon a baseline model. The chi-square statistic decreases to 122.68 from the baseline model value of 1119.74; additionally, our model has 94 degrees of freedom compared to 120 for the baseline model. This indicates that our model is a better fit than the baseline model.

Model 2 (Figure 4; Supplemental Table 3) uses a similar SEM model with our alternative measure of *In Situ* Adaptation (Building). In this model, Future Concern is significantly associated ($b = 0.27$; $p<0.1$) with increased willingness to Retreat, but does not have a significant relationship with *In Situ* Protection. High values of Past Perception (i.e., greater belief that storm severity and frequency has increased over the last 20 years) is associated with *In Situ* Adaptation ($b =0.55$; $p<0.05$), but is not significantly associated with Retreat. The chi-square statistic decreases to 124.98 from the baseline model value of 1119.23; additionally, our model has 94 degrees of freedom compared to 120 for the baseline model. This indicates that our model is a better fit than the baseline model.

Finally, Model 3 (Figure 4; Supplemental Table 4) looks at an aversion in using any of the three adaptive techniques, referred to as a non-protective response. We find a strong, negative relationship ($r = -0.93$; $p<0.01$), whereby low Past Perception of storm frequency and magnitude are associated with higher likelihood of not taking a protective response. The chi-square statistic decreases to 117.08 from the baseline model value of 1134.10; additionally, our model has 83 degrees of freedom compared to 105 for the baseline model. This indicates that our model is a better fit than the baseline model

5.3 Un-Standardized SEM Results

Un-standardized models results are also reported (Figure 4), and are more useful for comparing across models, allowing for direct comparisons between the relative influences of the paths in Models 1-3. Models 1 and 2 are demonstrably similar, indicating that similar patterns are at play for different types of *In Situ* adaptation strategies. The main difference between them is that negative impact of future worry is significant in Model 1, but is not significant (though is still negative) in Model 2. Comparing these paths to Model 3 shows an even more interesting change in relationships. Here, perception of the past has a strong *negative* influence on the resident's inclination to not engage in protective responses. This indicates that residents who think that flooding and storm conditions have *improved* over the last twenty years will not be open to considering either *in situ* or out-migration adaptive strategies. Our results are shown in Figure 4, and in a detailed table in the Supplemental Materials (Tables S2-4).

6. Discussion and Conclusions

We use SEM to analyze data on resident perspectives to past experiences and trends and future concerns regarding climate change conditions to better understand how different considerations would impact their willingness to engage in different adaptive measures. We compare reported openness to *In Situ* Adaption strategies, Retreat, and Non-Protective Responses. Our results suggest that different perceptions of past conditions and trends and future risks lead to dramatically different adaptive responses, as mediated by previous self-reported exposure. This is further supported by the limited correlation between the willingness to protect property or structures (*In Situ* Adaptation) and the willingness to migrate (Retreat), indicating that individuals are generally open to engage in either *in situ* or retreat responses, but not both. Taken together, the results indicate that there is a need for a more nuanced understanding of individual perceptions in terms of the effect on protective or non-protective responses.

This finding is explicated in our series of SEM models (Figure 4), where we see dramatic differences in the relationships between latent variables and adaptation responses. For example, increased Future Concern is associated with a willingness to retreat (or an acceptance that this may one day become inevitable), but it is negatively associated with *in situ* Adaptation measures. Similarly, a Past Perception that flooding and storm conditions have been getting worse over the last twenty years is associated with willingness to engage in *in situ* Adaptation measures, but negatively associated with non-protective responses.

Our results suggest that respondents' openness to different adaptation options reflects that they are reacting to dramatically different perspectives. However, future studies will need to confirm the directionality of these findings; are residents set in their decisions about outcomes, and therefore change their recollection and reporting of the experience, or are these outcome decisions fluid as residents continue to experience disasters and hear about future risks to their lives and homes? If we can presume, or confirm, that it is the latter, then local and state governments will have a powerful tool at their disposal that should inform their development of policies and risk communication strategies.

For example, a higher recollection and reporting of past exposure to flood risks and events is associated with an increased likelihood of residents to implement protective strategies *in situ*. It may be possible that the residents' recollection of past exposures can be enhanced by informing them (through models of past events, local stories of flood experiences collected from the community, or other means). If this is the case, then targeted education campaigns emphasizing these past events could contribute to homeowners implementing protective strategies on their property. This aligns with work by Slovic et. al. (2012) emphasizing the importance for "experiential systems" of risk assessment; and Kunreuther et. al. (2001) which emphasizes that rich contextual information helps laypeople understand risk for events with low probabilities. However, further research is necessary to establish this concretely. Future education campaigns should be bookended with residential surveys and interviews designed to understand shifting residential perspectives from before and after the implementation of education strategies centered on communicating the impact of past disaster events.

Comparatively, future concern is positively associated with retreat outcomes and negatively associated with non-protective responses. If we better understand how this fear is formed through future research, we can create strategies for informing residents about the real risks they face in a future defined by climate change. If information campaigns are successful in conveying this risk, it could lead to supported and well planned (rather than ad hoc) out-migration in particularly at risk areas. Further, state and local governments could focus their efforts on homes that are too vulnerable to protect using site-based mitigation strategies over the long term. Such outreach could be activated in the aftermath of major storm events, when federal funding becomes available for floodplain buyouts and other mitigation measures (Salvesen et al. 2018), where information is already provided to increase participation in the buyout program. Again, such campaigns would need to be paired with longitudinal research to better understand their impacts.

Returning to our hypothesis, we see support for the notion that protection and retreat strategies are not *perceived* as progressive strategies; instead, these strategies appear to be perceived to be dichotomous. This suggests that residents either want to sink expenses into place to protect their existing home, or they will want to migrate before accruing significant costs or losses. This does not seem to reflect the hypothetical model of progressive adaptation to evolving risk (McLeman 2017).

However, this study looks at resident perspectives on these options from a single point in time. There is a difference between the long-term adaptation pathway that results from multiple, independent decisions over time, relative to the perceived, a priori pathway that an individual articulates in the face of their own exposures, past perceptions, and future concerns. Therefore, we must note that our findings do not mean that residents will not *act* in accordance with a progressive adaption strategy over the long term, especially when faced with the experience of gradually increasing risks that trigger sequential thresholds. Nor do our findings suggest that residents will succeed in enacting necessary protection structures, even when they appear to be amiable to the idea. Rather, we anticipate that residents' openness to different adaptation strategies will shift under increasingly severe risk and SLR conditions, which may drive a shift in the relationship between adaptations strategies and perceptions of past events and future concerns.

Therefore, while our results better reflect the model developed by Black et. al. (2011) emphasizing a more bifurcated decision outcome from a single point in time, the forces of environmental degradation may result in progressive decisions that may closer resemble McLemen's (2017) model over a period of years (refer back to Figure 1A and 1B). We offer our own conceptual diagram to account for this theory, shown in Figure 5. In our diagram, we anticipate that households will face a series of events that can trigger the decision to protect one's home, retreat, or to keep the status quo. While that decision is discrete at any point in time, those who remain in place (in both protected and non-protected homes), may continue to make subsequent decisions related to additional storm events or in the face of worsening climate change. Through this, some households will stay until they can no longer and then retreat, while others will initially protect in place and retreat later. Under this conceptualization, we assume that the land in question will become unable to support housing based on current climate change projection, and retreat will be inevitable at a distant point in time. Perspectives on what decisions are made and when could still reflect changes to the relationship pathways between Exposure, Past Perception, and Future Concern.

[Insert Figure 5 about here]

A major limitation with this type of research is that surveys inherently examine the experiences of those who remain, critically omitting those who have already retreated due to past hazards.

Additional studies in this area are necessary 1) to establish how perspectives shift and influence future actions over a longer period (and in the face of accruing storm and flooding experiences; i.e., longitudinal studies); 2) to determine current and past drivers of retreat (ensuring that we avoid the "survivor bias" of those residents who remain); and 3) to determine the relationship between types and sizes of events and how they trigger shifts in perspective.

Still, our findings help inform our understanding of the factors that prompt resident willingness (and similarly, unwillingness) to consider mitigation measures, generally. Understanding when and why residents may be willing to retreat or protect themselves is critical to governments' ability to mitigate long-term exposure and risk at the individual and community level. Moreover, this information is critical to informing the strategies that local, state, and federal governments use in approaching and encouraging individuals to take proactive measures to mitigate increasing climate risk to their properties, livelihoods, and health. These findings, and results from future studies, can be used to inform communication strategies that may prompt residents to take precautionary measures to reduce their personal risk, as well as the risk of their communities and the state at large.

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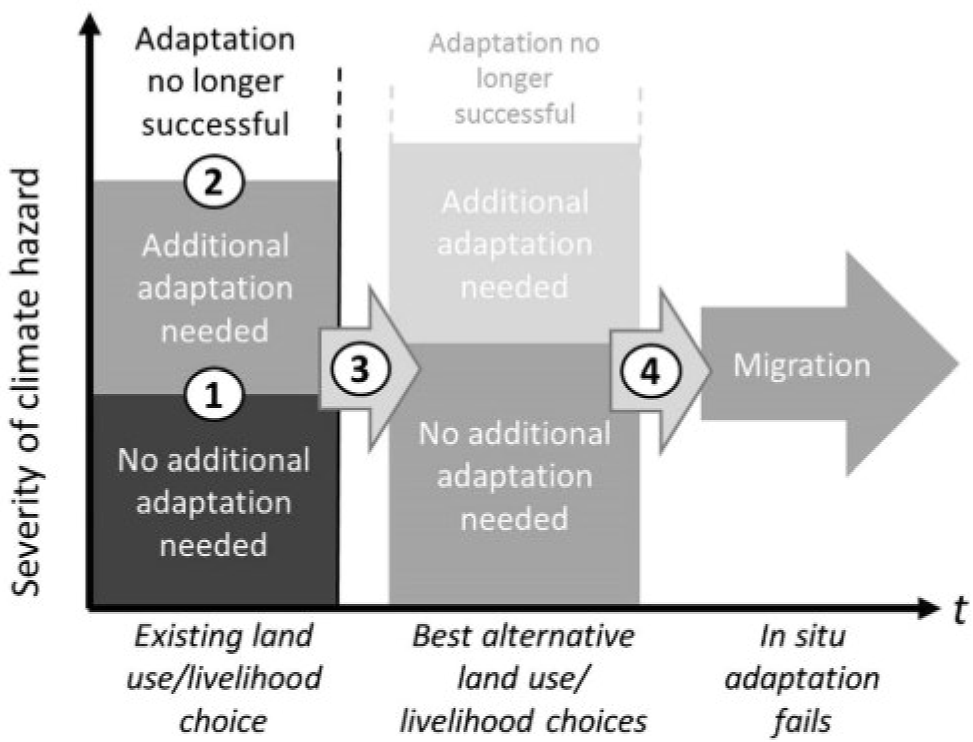
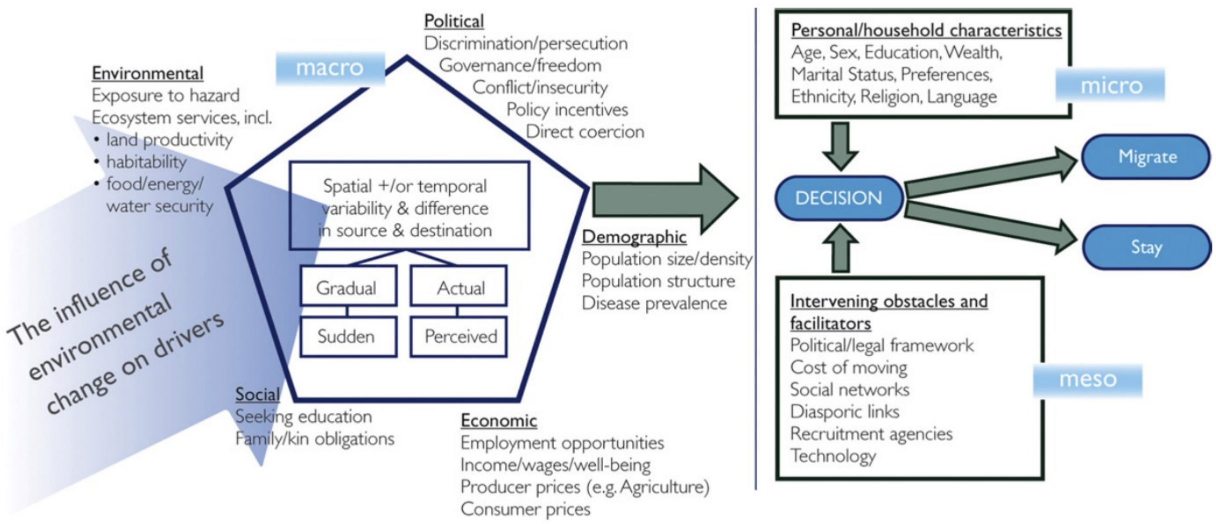
Figures

Figure 1: Alternative frameworks describing adaptation pathways. Panel A: McLeman (2017) threshold-based adaptation pathways framework. Panel B: Black, Adger et. al.'s (2013) migration theory-based framework adapted to emphasize climactic and environmental drivers.

Panel A: Adaptation and thresholds in a hypothesized system. This system implies progressive adaption strategies that accelerate in response to deteriorating environmental conditions.



Panel B: A conceptual framework for the 'drivers of migration'. This builds off of traditional migration theory adding in considerations for environmental change in the light of its heightened importance in the era of climate change



Political
Discrimination/persecution
Governance/freedom
Conflict/insecurity
Policy incentives
Direct coercion
macro
Environmental
Exposure to hazard
Ecosystem services, incl.
• land productivity
• habitability
• food/energy/ water security
Spatial +/or temporal variability & difference in source & destination
Gradual
Actual
Sudden
Perceived
The influence of environmental change on drivers
Social
Seeking education
Family/kin obligations
Economic
Employment opportunities
Income/wages/well-being
Producer prices (e.g. Agriculture)
Consumer prices
Demographic
Population size/density
Population structure
Disease prevalence
Personal/household characteristics
Age, Sex, Education, Wealth, Marital Status, Preferences, Ethnicity, Religion, Language
micro
DECISION
Migrate
Stay
Intervening obstacles and facilitators
Political/legal framework
Cost of moving
Social networks
Diasporic links
Recruitment agencies
Technology
meso

801

802

Figure 2. Map of surveyed residents and floodplains in North Carolina's Albemarle-Pamlico Peninsula (APP).

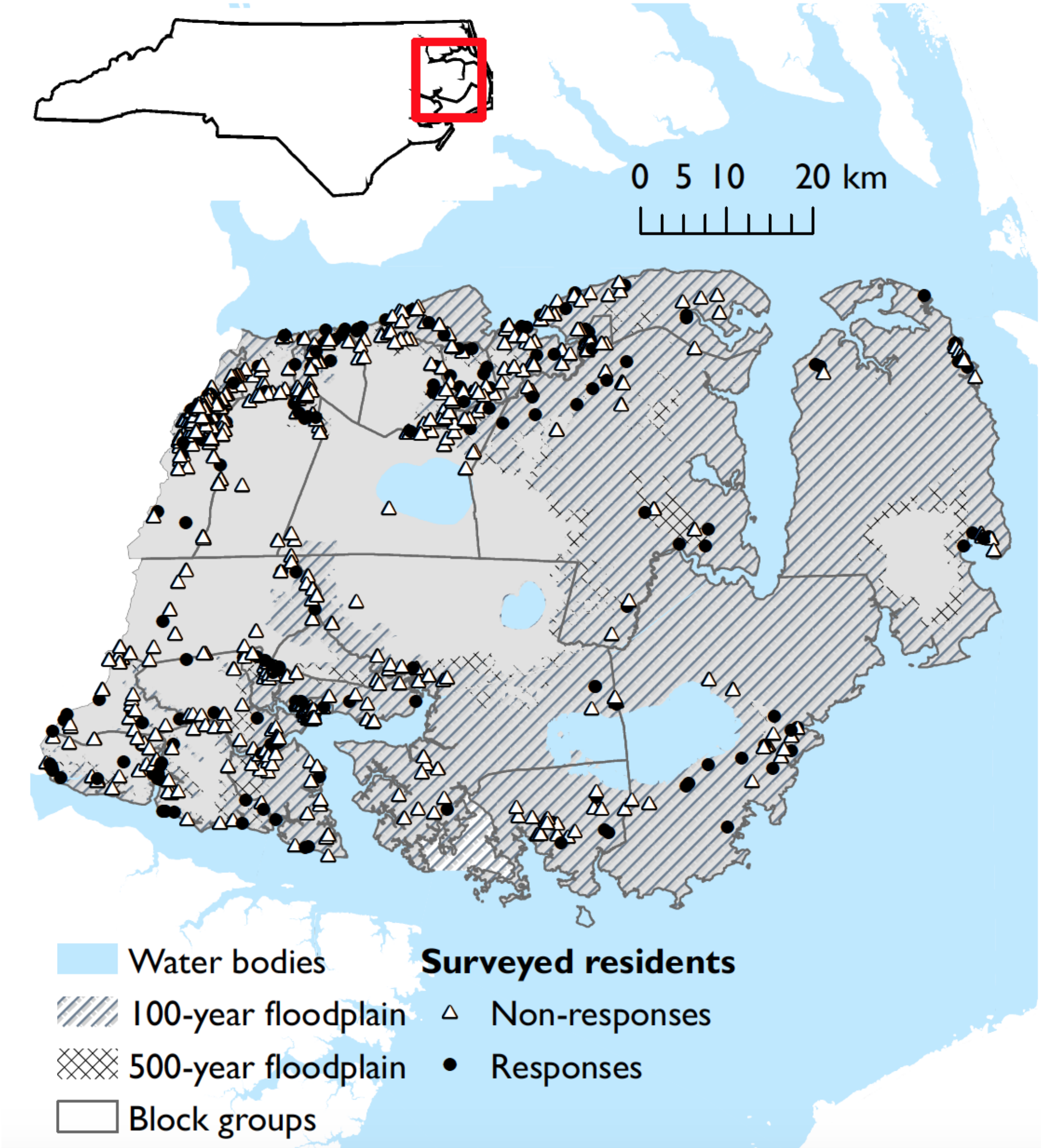


Figure 3: SEM model conceptual design linking measured explanatory variables (refer to Table 1), latent measures (Exposure, Past Perception, and Future Concern), and adaptive behaviors (Retreat, Protection, Non-Protective Response).

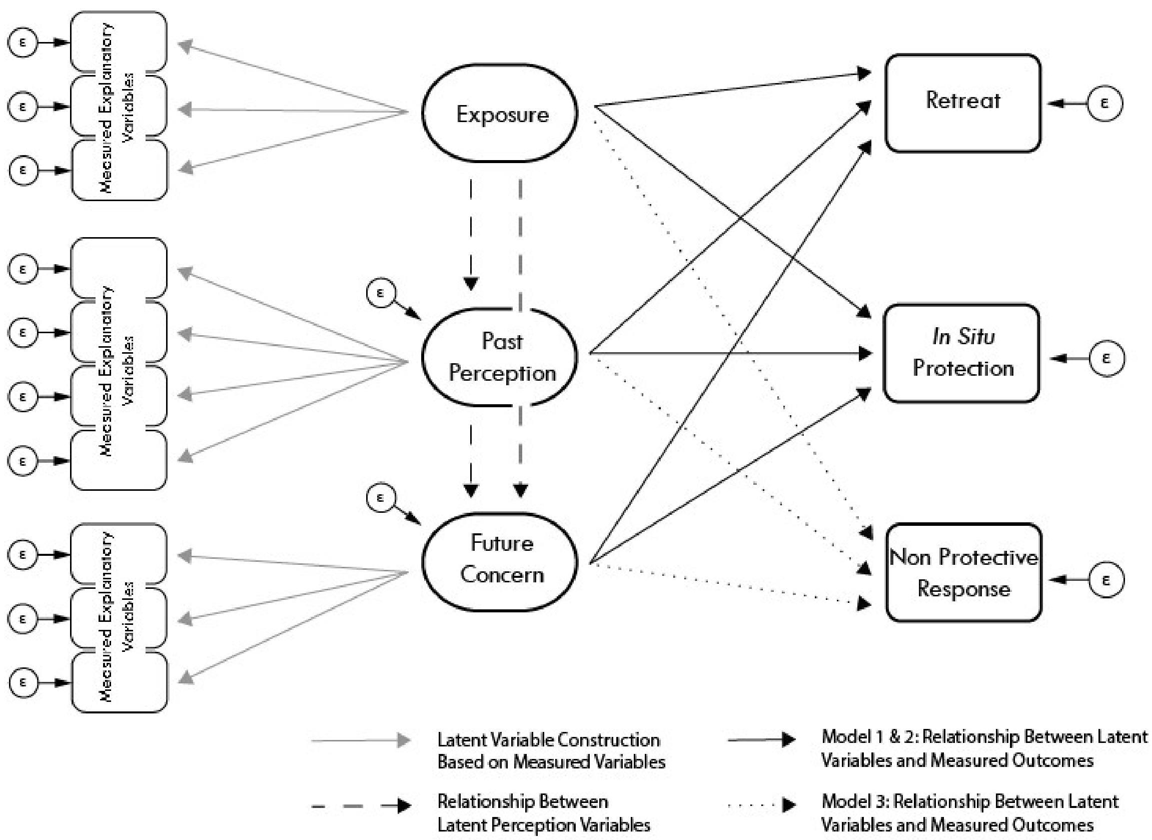


Figure 4: Standardized (black) and un-standardized SEM models (gray). Model 1) Outcome variables: Retreat and *In Situ* Adaptation (property). Model 2) Outcome variables: Retreat and *In Situ* Adaptation (building). Model 3) Outcome variable: Non-Protective Response. **p<0.1; **p<0.05; ***p<0.01. N = 147.* Refer to Supplemental Tables 2 – 4 for more detailed output.

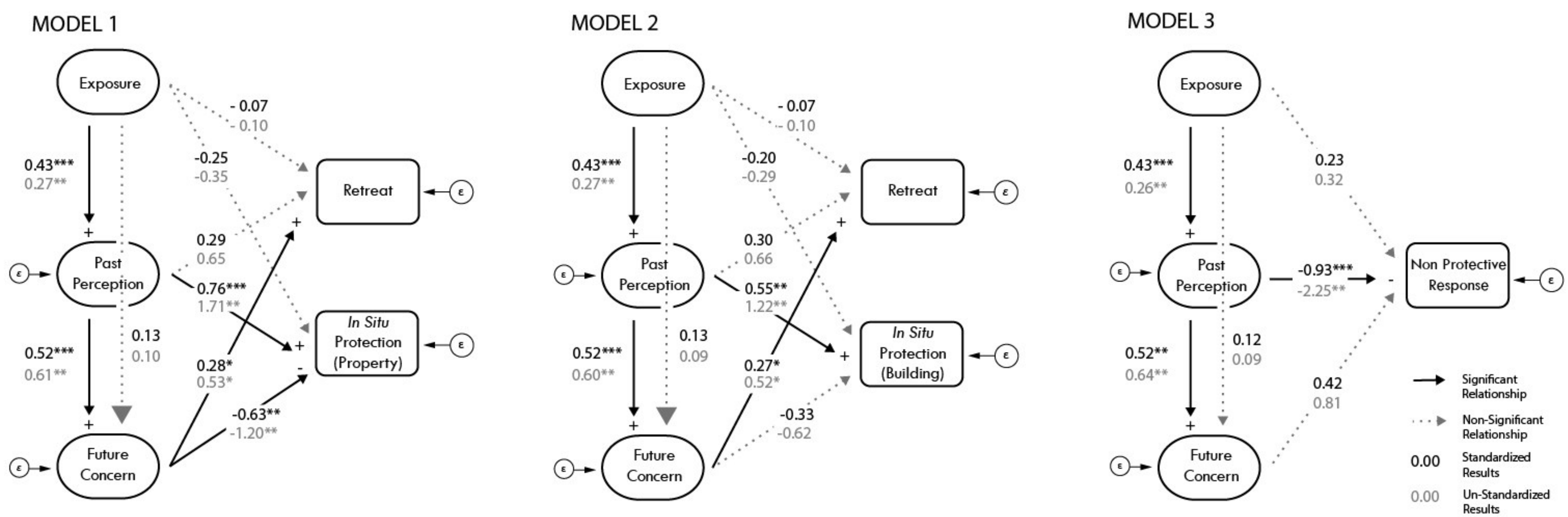
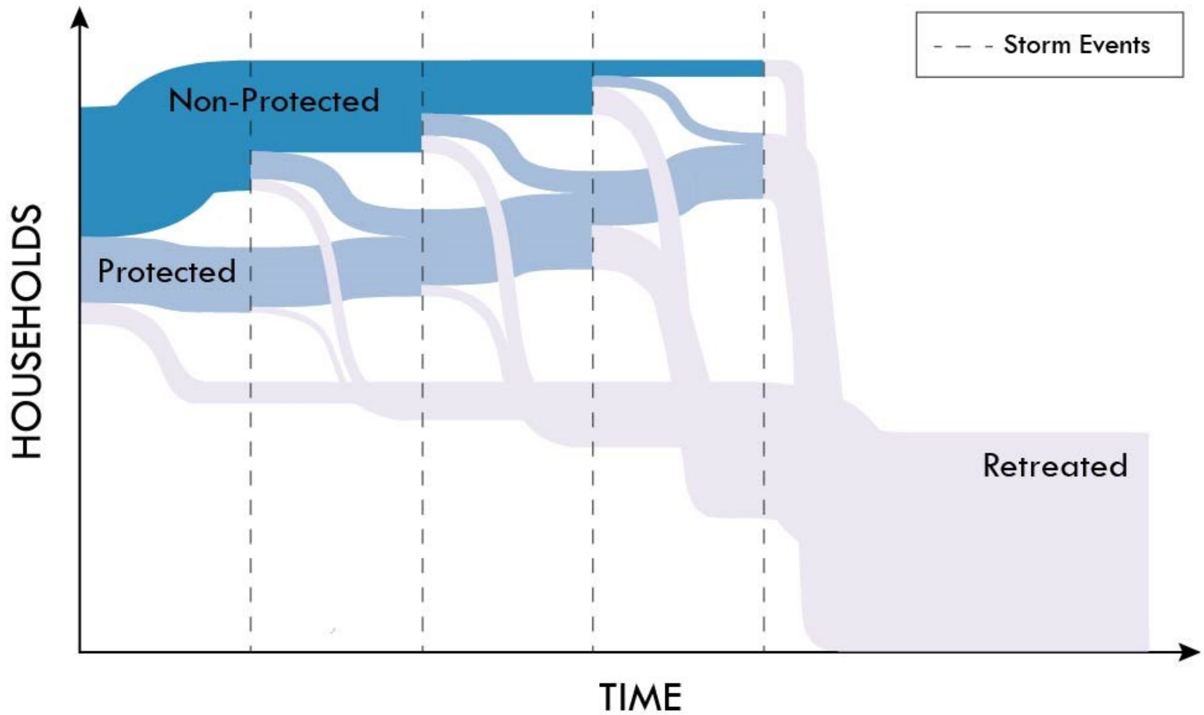


Figure 5: Conceptualized framework regarding a series of discrete choices in the face of multiple storm events, considering that choices may change as conditions deteriorate over time.



Tables

Table 1: Construction of latent variables based on measured explanatory variables. Survey question linked to explanatory variables and coding scheme are shown. Superscript letters indicate sets of variables with linked error terms

Latent Variable	Explanatory Variables	Description	Coding
Exposure	Structural Damage	Have you ever experienced structural damage to your home due to storm-related flooding?	(1) Yes (0) No
	FFE Damage	Have the contents of your home been damaged by storm related flooding?	(1) Yes (0) No
	Property Damage	Have other areas of your property ever been damaged or affected by storm-related flooding?	(1) Yes (0) No
	Standing Water	In the past 5 years, have you noticed any standing water on your property?	(1) Yes (0) No
	Hurricane Matthew	Was your property impacted by Hurricane Matthew (October 2016)?	(1) Yes (0) No
	Previous Storms	Have you been affected by a hurricane or another storm in the past?	(1) Yes (0) No
	Evacuation	Have you been evacuated due to a storm in your area?	(1) Yes (0) No
Past Perception	Strengthening Storms[a]	Over the past 20 years, what do you believe has happened to the strength of storms?	(1) Storms are getting a lot milder (2) Storms are getting milder (3) Strength has not changed (4) Storms are getting somewhat stronger (5) Storms are getting a lot stronger
	More Frequent Storms[a]	Over the past 20 years, what do you believe has happened to the frequency of storms?	(1) Storms are much less frequent (2) Storms are somewhat less frequent (3) Storm frequency has not changed (4) Storms are getting somewhat more frequent (5) Storms are getting much more frequent
	Property Flooding	What changes have you noticed in flooding on your property over the last 20 years	(1) Much less flooding (2) Somewhat less flooding (3) No changes in flooding (4) Somewhat more flooding (5) much more flooding
	Community Flooding	What changes have you noticed in flooding in your community over the last 20 years	(1) Much less flooding (2) Somewhat less flooding (3) No changes in flooding (4) Somewhat more flooding (5) much more flooding
Future Concern	Property Value	I am concerned with the value of my property in the future	(1) Strongly Disagree (2) Somewhat Disagree (3) Neither Agree nor Disagree (4) Somewhat Agree (5) Strongly Agree
	Environmental Property Changes[b]	I am concerned with how environmental changes may affect my property in the future	(1) Strongly Disagree (2) Somewhat Disagree (3) Neither Agree nor Disagree (4) Somewhat Agree (5) Strongly Agree
	Environmental Community Changes[b]	I am concerned with how environmental changes may affect my community in the future	(1) Strongly Disagree (2) Somewhat Disagree (3) Neither Agree nor Disagree (4) Somewhat Agree (5) Strongly Agree

Table 2: Adaptive response (outcome) variables, the survey question they were operationalized from, their description, and coding.

Conceptual Representation	**Explanatory Variables**	**Description**	**Coding**
Retreat	Retreat	Could you foresee that flooding would ever force you to move from your property?	(1) Yes (0) No
In Situ Protection (buildings)	Building Protection WCS	Imagine there is flooding on your property and it is severe enough to damage buildings or structures: How frequent would this flooding need to be to prompt you to install / upgrade WCS	(1) There is a frequency that would lead to installation / upgrades (0) Would never install water control structures
In Situ Protection (property)	Land Protection WCS	Imagine there is flooding on your property and it is not severe enough to damage buildings or structures: How frequent would this flooding need to be to prompt you to install / upgrade WCS	(1) There is a frequency that would lead to installation / upgrades (0) Would never install water control structures
Non-Protective Response	No Adaption	A composite score reflecting an unwillingness to engage with any of the above adaptation techniques	(1) 0 to all of the above responses (0) 1 to any of the above responses

Table 3: Correlation matrix of outcome variables (n=147). *p<0.1; **p<0.05; ***p<0.01

	Retreat	*In Situ* Protection (Buildings)	*In Situ* Protection (Property)	Non-Protective Response
Retreat	1.000			
	.			
In Situ Protection (Buildings)	0.087	1.000		
	(0.294)	.		
In Situ Protection (Property)	-0.015	0.858***	1.000	
	(0.855)	(0.000)	.	
Non-Protective Response	-0.369***	-0.7303***	-0.679***	1.000
	(0.000)	(0.000)	(0.000)	.