Spatial Implications of Flood Exposure and Relocation Attitudes among Older Populations in Hampton Roads, VA

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Abstract (academic)

Coastal communities along the eastern seaboard are continuously exposed to flooding and related impacts, compromising the health and safety of their residents and especially of more vulnerable older populations. In cases where structural protection and floodproofing measures may not protect households from all types of flooding, relocation may represent the most effective long-term adaptation option. However, the extent to which older residents in Hampton Roads, Virginia are exposed to such flooding is not well understood, nor are the factors influencing their relocation attitudes. Thus, the main objective of this research is to understand both the exposure to flooding and evaluate attitudes towards relocation among older residents in Hampton Roads. This study uses a mixed methods approach to analyze flood exposure and attitudes towards relocation among older adults living in this area. First, a geospatial analysis was conducted to assess the change in flood risk in Hampton Roads over a period of 60 years and exposure to older populations, aged 60 and over. Then the survey data were used to conduct a correlation analysis to examine the relationship between survey responses and respondents' willingness to consider relocation. The geospatial analysis showed that flood exposure in this area does not increase linearly with time, with several block groups experiencing accelerated levels of flood increases from 2000-2060. Most of the municipalities which experience high overlap between flood extent and older population percentages are urban and see dramatic increases in flood exposure from 2000-2060. The statistical results show that willingness to consider relocation is correlated to several variables measuring sociodemographic characteristics, place attachment, and flood exposure, and less to other considerations influencing the decision to permanently relocate. The most influential factors driving relocation attitudes are financial, where residents would consider relocation if compensated or offered similar housing elsewhere. Finally, a large proportion of respondents (40.28%) would prefer to permanently move to either a different region or different state should flooding continue in their community. The results of this study can help community leaders and policymakers to better understand the flood outcomes and assistance needs of their older populations living in flood-prone areas.

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General Audience Abstract

Coastal communities along the Eastern United States are constantly exposed to flooding and related impacts. Hampton Roads, Virginia is experiencing higher-than-average sea level rise, which is increasing flooding and its impacts. This area is also a preferred retirement region, where older populations prefer to move. Older populations are more negatively affected by these impacts due to chronic health conditions like diabetes and hypertension, which require easy access to health care services, as well as mobility constraints. The objective of this research is to identify areas within Hampton Roads that have a significant overlap between flooding and older populations and to understand what factors are affecting older residents' attitudes towards relocation. This study answers the following questions regarding the overall objective: 1) What is the exposure to coastal flooding of older populations living in urban areas in Hampton Roads? and 2) Which aspects of socioeconomic circumstances, experiences with flooding, and flood-related concerns affect attitudes about permanent relocation among older coastal residents? To answer these questions, a geospatial analysis was conducted, followed by a survey analysis. There are high levels of overlap between older populations and flooding in urban municipalities, and flood exposure is expected to dramatically increase between the years 2000 and 2060. From the survey, older respondents favor monetary incentives for relocation as opposed to other factors. The results from this study should be used by local policymakers for more well-informed decisions that incorporate community members in the planning and relocation process.

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Preface/Attribution

Dr. Anamaria Bukvic was my committee chair and academic advisor for my thesis. She guided me through the research process and helped me understand how to become a more critical writer and thinker. Her expertise in coastal resilience and adaptation was essential for this research.

Dr. Ryan Calder was a member of my thesis committee. His background in environmental health impacts and keen eye helped me identify effective research strategies. His questions and critiques helped guide me through my research from a public health perspective.

Dr. Yang Shao was a member of my thesis committee. His background in geospatial information technology was vital in the formulation of my geospatial analysis methodology. Primarily, he aided me in my analysis and calculation of flood exposure change over time.

Each of my committee members brought a unique perspective, feedback, and encouragement throughout this research.

1. Introduction

Coastal communities along the eastern seaboard are continuously exposed to flooding and related impacts as a result of sea level rise (SLR), compromising the health and safety of their residents and a more vulnerable older population. The frequency and severity of coastal flood events have increased due to climate change (Bradford et al. 2012). These threats are further compounded by the presence of a growing population in coastal areas, and more specifically by older populations that often select these settings as their retirement destinations (Frey, 2003 & Sharma, 2015.) By 2030, the number of people over 65 years of age living in the U.S. is expected to reach 72 million - a more than 100% increase from the 2003 population estimates (Wang & Yarnal, 2012). As this older cohort grows larger, so does its diversity. With a diverse population encompassing several races and ethnicities, economic classes, and health levels, this growing group of older adults in the U.S. will face new vulnerabilities as it becomes socioeconomically more heterogeneous. When older adults migrate to coastal regions, they sometimes opt to "age in place" or "remain living in the community, with some level of independence" (Davey et al. 2004), regardless of multiple physical and environmental risks in their immediate surroundings.

Older Population Vulnerability. Increasing flood exposure is a significant threat to socially vulnerable communities with limited ability to cope with disasters (Kleinosky et al. 2007). Studies have found that socially vulnerable populations in coastal Virginia face disproportionate exposure to sea-level rise; however, the vulnerable communities vary greatly depending on the indicators of vulnerability measured (e.g. Kleinosky et al. 2007). According to the IPCC (1998, p.3), vulnerability is defined as "the extent to which a natural or social system is susceptible to sustaining damage from climate change." However, vulnerability is not homogenous, and certain populations are at higher risk due to varying factors of economic, social, human, and physical placement (Birkmann et al. 2013). Specifically, age plays a significant role in a person's ability to cope with risk, and older populations tend to be more vulnerable to experiencing negative health impacts during and after disasters (Prohaska & Peters, 2019, Malik et al. 2018). Assessing vulnerability goes beyond the analysis of physical stressors like SLR, and examines how affected systems adapt and respond to stressors (Kleinosky et al. 2007).

Coastal areas are also preferred retirement areas for older populations regardless of the accelerated risk of coastal flooding (Bukvic et al. 2018). Older populations have higher physical and psychosocial vulnerabilities to natural hazards, disasters, and weather extremes, (Gamble et al. 2012; Carter et al. 2014; Lamb et al. 2008; Perry & Lindell, 1997) and higher mortality rates during disasters (Benson & Aldrich, 2007; Wood & Bourque, 2018; Terti et al. 2017). In fact, throughout all stages of disasters, older people are at a greater risk of health-related consequences and are slower to recover from disasters than younger age groups (Morrow, 1999). An example of this heightened vulnerability is shown in the aftermath of Hurricane Katrina in 2005 when the majority of all hurricane-related deaths (70%) were of older people, aged 65 and above (Wang & Yarnal,

2012). Older populations are more likely to experience conditions that increase their vulnerability to disasters such as chronic health conditions (hypertension, diabetes, etc.), physical and cognitive difficulties, and reliance on others for daily activities (Behr & Diaz, 2013). Consequently, these populations would be expected to be the first to evacuate from flood-prone areas because of their heightened vulnerability. However, Behr and Diaz's (2013) findings suggest the opposite. Because of their lack of mobility and other health-related difficulties (e.g., dependency on assistive devices or cognitive limitations), older populations are more likely to shelter in place during disaster events than evacuate (Behr & Diaz, 2013). Further, during disaster events, older populations are less likely to have safe and efficient means of transportation, prompting many to shelter in place, increasing their risk of drowning, electrocution, and physical trauma (Lane et al. 2013). Such negative effects make older residents more vulnerable to disaster displacement, but not always. For example, Kamo et al. (2011), found that life experiences of older adults may better prepare them to cope with disasters than younger populations, where older individuals experience higher levels of psychological wellbeing post-displacement than their younger counterparts.

Sea Level Rise in Hampton Roads. According to Tebaldi et al. (2012), low-lying coastal communities will face increased flooding due to the augmentation of water levels resulting from sea level rise. Coastal Virginia is also susceptible to tidal inundation and storm surge flooding due to its low-lying topography (Kleinosky et al. 2007). Hampton Roads is specifically vulnerable to relative SLR through a combination of land subsidence and low-lying geography. More specifically, glacial Isostatic adjustment is a driver of land subsidence in this area due to the Southern Chesapeake Bay's historical location relative to the Laurentide ice sheet (Eggleston & Pope, 2013). Such subsidence is predicted to have a rate of 1mm/year (Engelhart et al. 2009, Engelhart & Horton, 2012), though this is not uniform across the entire region (Eggleston & Pope, 2013). Additionally, Hampton Roads has the highest rate of sea-level rise (3.9mm/year) across the U.S. Atlantic coast (NOAA, n.d.)

Disaster Displacement and Relocation. Displacement from disasters like hurricanes has several negative impacts, many of which are augmented by older age (Behr & Diaz, 2013; Bukvic et al. 2018; Morrow, 1999). Factors like education, family structure, and disability status have varying effects on the psychological well-being of older people in disasters (Lane et al. 2013; Kamo et al. 2011). Disaster displacement can lead to interruptions in the acquisition of medical care, further exacerbating pre-existing health conditions, especially among older individuals (Lane et al. 2013). Around 80% of older adults experience one or more chronic conditions such as diabetes, hypertension, and arthritis (Aldrich & Benson, 2008) that require regular visits to health care facilities and pharmacies, and continued flooding can disrupt access to these services. Older people are more likely to experience long-term health impacts from disruptions of such networks necessary for the management of chronic health conditions post-disaster (Behr & Diaz, 2013).

As coastal flooding and associated impacts increase, many communities are faced with three options to adapt: protect, accommodate, or retreat/relocate (Dedekorkut-Howes et al. 2020).

Relocation away from flood zones in coastal communities must be examined on a case-by-case basis and must acknowledge the socioeconomic circumstances of residents to most effectively reduce flood risk and reduce hardships. Implementing relocation effectively requires pre-disaster planning (Ferris & Weerasinghe, 2020). Further, effective relocation planning should include equitable involvement of residents and other stakeholders affected by repetitive hazards and disasters (Farbotko et al. 2020). Finally, to support, protect, and empower communities facing issues such as flooding, relocation efforts must take place before major disasters occur, spearheaded by committed and supportive local leaders (Ferris & Weerasinghe, 2020). When these preemptive planning efforts are delayed, relocation is likely to make vulnerable communities suffer more, and leave them with fewer options to design the relocation process that will meet the needs of all households in need of relocation (Shearer, 2012). While a growing number of studies try to understand the physical and socioeconomic factors that influence needs and preferences for relocation, there is still a research gap in contextualizing this knowledge exclusively for older populations.

Farbotko et al. (2020) state that planned relocation, while important in protecting vulnerable populations from climate change impacts, also has the potential to exacerbate preexisting vulnerabilities if not implemented correctly. Relocation of the older population is especially likely to exacerbate their existing physical and mental health ailments, if it is abrupt and unplanned (Castle, 2001), and can dissipate culturally important areas (Farbotko et al. 2020). One such effect is known as relocation stress syndrome, where an individual "experiences physiological disturbances and/or psychological disturbances as a result of a transfer from one environment to another" (Brugler et al. 1993, p. 45). To combat the several disparate health impacts that relocation can have on the older populations, community involvement and engagement in the planning process are essential, (Castle, 2001). When older populations are prepared ahead of disasters via planning and discussions, relocation becomes less likely to cause adverse health effects (Castle, 2001 & Ferris & Weerasinghe, 2020). Relocation can, however, provide new livelihood opportunities and mitigate climate risks in vulnerable populations when it is done with adequate financial capability, legal framework, land consideration, and equitable human rights considerations (Farbotko et al. 2020; Piggott-McKellar et al. 2019; Ferris & Weerasinghe, 2020). This type of disaster planning can benefit entire communities by providing necessary preparedness tools to help mitigate disaster effects.

Proximity and Risk Perception. Risk perception is an assessment of a hazard's probability and the probability of its accompanying, mostly negative impacts as perceived by society (Lechowska, 2018). Bukvic et al. (2018) found that proximity to flooding hazards plays an important role in determining the course of adaptation actions a household may pursue. Risk perception is strongly influenced by proximity to the hazardous event (Haynes et al. 2008; Peacock et al. 2005), and populations living closer to coastal hazards such as storm surges and sea level rise are generally more concerned about their risk and rebuilding rules than their counterparts who live farther from the flood zone (Bukvic et al. 2018). A study from New Zealand found that residents living close

to the shoreline were more likely to believe in climate change than those living farther inland, due to their experiences with climate change-related impacts (Milfont et al. 2014). Risk perception plays an integral part in managing flood risk and is generally lower than the measured flood risk (Lechowska, 2018), suggesting residents tend to underestimate risk. Accordingly, it is essential to disseminate accurate information to officials who can ensure adaptation and resilience planning efforts are adequately aligned with flood risk. When public officials understand how their community views flood risk, they can more effectively implement policy and spread information meant to increase trust in the government, improving the capability to manage floods and increase social resilience to disasters (Lechowska, 2018). Sociodemographic variables also have significant impacts on the vulnerabilities of populations experiencing flooding. A study conducted by Türkkan & Hırca (2021), which examined the role of sociodemographic determinants on flood risk perception, found that more educated respondents had higher levels of confidence in their ability to respond to flood warnings.

Problem Statement

As sea levels continue to rise, the questions of the possibility of relocation become more imminent. While several studies address flood risk in Hampton Roads (e.g. Kleinosky et al, 2007; Liu et al, 2015), the vulnerability of the elderly to flood risk (e.g. Wang & Yarnal, 2011), and the role of proximity on relocation (e.g. Bukvic et al. 2018), there have been no studies evaluating all of these three components together. Thus, this Thesis will supplement previous studies in the fields of coastal and human geography by answering important questions about older populations' vulnerability to coastal flooding and relocation. Liu et al. (2015), focused on Hampton Roads in their analyses of the physical, built environment, and household vulnerabilities to storm surge flooding. Their study, however, did not incorporate specific demographic information on the vulnerability of older populations. Kleinosky et al. (2007) also analyzed storm surge flooding in Hampton roads and used GIS to create composite vulnerability maps, but did not focus on either relocation or older populations. Some studies do analyze vulnerability to coastal flooding among older populations, such as Wang & Yarnal (2011), however, they do not specifically address relocation as an adaptive strategy to flooding. Additional research is needed to understand how proximity to flooding affects flood risk perceptions of older residents, specifically in Hampton Roads.

Research Objective and Questions. An improved understanding of the explicit flood risk among older populations in Hampton Roads is important for local planning, especially for the consideration of different adaptation and resilience interventions. Studies have shown how flood risk aligns with older population households (Bukvic & Harrald, 2019; Bukvic et al. 2015; Kleinosky et al. 2007), but none has analyzed how these residents perceive their risk based on prior experiences with flooding and how that influences their thinking about relocation. Creating a better understanding of how perception aligns with flooding risk on a local scale will allow the communities in Hampton Roads to design policies and programs that will address the unique needs

of older residents, whether to support them to stay in place or relocate to a safer area elsewhere. A more informed policy that considers local attitudes can be implemented in the regions with high physical risk, preparing a vulnerable community and bolstering resilience. This study will evaluate flood exposure among older populations in the Hampton Roads study area and identify which considerations are more important in willingness to consider permanent relocation due to flooding. Namely, it will answer the following questions:

1. What is the exposure to coastal flooding of older populations living in urban areas in Hampton Roads?
2. Which aspects of socioeconomic circumstances, experiences with flooding, and flood-related concerns affect attitudes about permanent relocation among older coastal residents?

2. Manuscript

Assessing flood risk and attitudes towards relocation among older coastal residents

Abstract

Coastal communities along the eastern seaboard are continuously exposed to flooding and related impacts, compromising the health and safety of their residents and especially of more vulnerable older populations. In cases where structural protection and floodproofing measures may not protect households from all types of flooding, relocation may represent the most effective long-term adaptation option. However, the extent to which older residents in Hampton Roads, Virginia are exposed to such flooding is not well understood, nor are the factors influencing their relocation attitudes. Thus, the main objective of this research is to understand both the exposure to flooding and evaluate attitudes towards relocation among older residents in Hampton Roads. This study uses a mixed methods approach to analyze flood exposure and attitudes towards relocation among older adults living in this area. First, a geospatial analysis was conducted to assess the change in flood risk in Hampton Roads over a period of 60 years and exposure to older populations, aged 60 and over. Then the survey data were used to conduct a correlation analysis to examine the relationship between survey responses and respondents' willingness to consider relocation. The geospatial analysis showed that flood exposure in this area does not increase linearly with time, with several block groups experiencing accelerated levels of flood increases from 2000-2060. Most of the municipalities which experience high overlap between flood extent and older population percentages are urban and see dramatic increases in flood exposure from 2000-2060. The statistical results show that willingness to consider relocation is correlated to several variables measuring sociodemographic characteristics, place attachment, and flood exposure, and less to other considerations influencing the decision to permanently relocate. The most influential factors driving relocation attitudes are financial, where residents would consider relocation if compensated or offered similar housing elsewhere. Finally, a large proportion of respondents (40.28%) would prefer to permanently move to either a different region or different state should flooding continue in their community. The results of this study can help community leaders and policymakers to better understand the flood outcomes and assistance needs of their older populations living in flood-prone areas.

2.1 Introduction

The frequency and severity of coastal flood events have increased due to climate change (Bradford, et al. 2012). These threats are further compounded by the presence of a growing population in coastal areas, and more specifically by older populations that often select these settings as their retirement destinations (Frey, 2003, Sharma, 2015). By 2030, the number of people over 65 years of age living in the U.S. is expected to reach 72 million - a more than 100% increase from the 2003 population estimates (Wang & Yarnal, 2012). When older adults migrate to coastal regions, they sometimes choose to 'age in place,' or "remain living in the community, with some level of independence" (Davey et al. 2004), regardless of multiple physical and environmental risks in their immediate surroundings. Coastal areas are also often preferred retirement areas for older populations regardless of the accelerated risk of coastal flooding (Bukvic et al. 2018). Older populations have higher physical and psychosocial vulnerabilities to natural hazards, disasters, and

weather extremes, (Gamble et al. 2012; one et al. 2014; Lamb et al. 2008; Perry & Lindell, 1997) and higher mortality rates during disasters (Benson & Aldrich, 2007; Wood & Bourque, 2018; Terti et al. 2017). An example of this heightened vulnerability is shown in the aftermath of Hurricane Katrina in 2005 when the majority of all hurricane-related deaths (70%) were of older people (Wang & Yarnal, 2012). Further, during disaster events, older populations are less likely to have safe and efficient means of transportation, prompting many to shelter in place, increasing their risk of drowning, electrocution, and physical trauma (Lane et al. 2013).

Coastal Virginia is susceptible to tidal inundation and storm surge flooding due to its low-lying topography (Kleinosky et al. 2007). More specifically, Hampton Roads is extremely vulnerable to relative SLR through a combination of land subsidence caused by glacial Isostatic adjustment (Eggleston & Pope, 2013). Further, the majority of Hampton Roads has an elevation less than 10m above sea level, increasing the overall flood risk (Kleinosky et al. 2007). Physical vulnerabilities to flooding are combined with social vulnerabilities like wealth, and socioeconomic household factors such as financial capability and health conditions (Liu et al, 2015). This is compounded by the rapid population growth occurring in Hampton Roads. From 2010 - 2021, the population of this region alone grew by 4.72% (Greater Hampton Roads, 2021). Additionally, the population of residents of Hampton Roads that are aged 65 and over is 14.64%, which is roughly 172,000 people (Greater Hampton Roads, 2021).

To adapt to coastal hazards like flooding, communities have three options, protect, accommodate, or retreat/relocate (Dedekorkut-Howes et al. 2020). Relocation away from flood zones in coastal communities must be examined on a case-by-case basis and must acknowledge the socioeconomic circumstances of residents to most effectively reduce flood risk and reduce hardships. Implementing relocation effectively requires pre-disaster planning (Ferris & Weerasinghe, 2020). Further, effective relocation planning should include equitable involvement of residents and other stakeholders affected by repetitive hazards and disasters (Farbotko et al. 2020). This study evaluates factors influencing attitudes towards permanent relocation due to coastal flooding among older populations in Hampton Roads. It uses an innovative approach combining a geospatial analysis with a survey to assess how actual flood risk aligns with perceived flood risk and attitudes towards relocation among these older respondents. Even if present flooding is not extreme enough to warrant relocation now, our flood projections for the near future highlight flood exposure potential, and can help residents understand their actual risk. However, regardless of the actual risk, some residents of flood-prone areas may be unaware of the dangers they face and may have a lower risk perception than necessary to avoid disasters.

Risk perception is an assessment of a hazard’s magnitude and probability, and how such hazard's impacts are perceived by an individual or a group. (Lechowska, 2018). Two studies examining risk perception and sociodemographic/proximity variables suggest that the most influential factor in determining risk perception was proximity to the hazardous event, with those living closer to the hazard generally perceiving risks as greater than individuals living farther away (Haynes et al. 2008; Peacock et al. 2005). A study from New Zealand found that residents living close to the shoreline were more likely to believe in climate change than those living farther inland (Milfont et al. 2014). Risk perception plays an integral part of flood risk management and is generally lower than the measured flood risk (Lechowska, 2018), suggesting residents tend to underestimate risk. Accordingly, it is essential to disseminate accurate information to officials who can ensure adaptation and resilience planning efforts are adequately aligned with flood risk.

Assessing coastal flooding's overlap with older populations in Hampton Roads on a municipal level will help identify which jurisdictions are at the highest risk, and can help policymakers and local governments make more informed decisions about their adaptation strategies, specifically relocation. This research aims to characterize flood exposure of older populations in the Hampton Roads study area and identify which factors are more important in willingness to consider permanent relocation due to flooding. Previous studies have explored overlap of flood risk with older populations (Bukvic & Harrald, 2019; Bukvic et al. 2015; Kleinosky et al. 2007), but none has analyzed how these residents perceive their flood risk based on prior experiences with flooding and how that influences their thinking about relocation. Additionally, the results from the survey analysis should be used as a guide to developing new research which explores the overlap between flooding and older in Hampton Roads and beyond.

2.2 Materials and methods

Study Locations. The study is focused on the Hampton Roads Planning District which contains 18 municipalities, and 1,169 Census block groups (**Figure 1)**. Of these 18 municipalities, 16 are considered to be urban, and only two, Southampton and Franklin City, are rural. Hampton Roads is located in the southeastern corner of Virginia and is the 34th most populous metropolitan area with the 38th largest economy in the U.S. (Sadler et al. 2017). This area is the second most vulnerable metropolitan area to SLR in the United States because of its land subsidence and low-lying geography, second only to New Orleans (Sadler et al. 2017). Further, the majority of Hampton Roads has an elevation less than 10m above sea level, increasing overall flood risk (Kleinosky et al, 2007). This is compounded by the rapid population growth occurring in Hampton Roads. From 2010 - 2021, the population of this region alone grew by 4.72% (Greater Hampton Roads, 2021). Additionally, the population of Hampton Roads residents age 65 and over is roughly 172,000 people (Greater Hampton Roads, 2021).With rapid population increase and climate change as a threat multiplier for hurricane impacts, regions like Hampton Roads will become even more vulnerable than before (Wang & Yarnal, 2012). Liu et al. (2015) found that urban areas within counties and independent cities such as Newport News and Hampton are more vulnerable to flooding than their rural counterparts due to physical location, densely built environment, and socioeconomic household factors such as financial capability and health fragility. This area also has the second largest port on the East Coast and is the central hub for tourism in Virginia (Kleinosky et al. 2007). Additionally, the largest naval base in the world, Naval Station Norfolk, is found in Hampton Roads along with several other military assets (Kleinosky et al, 2007). Altogether, Hampton Roads is home to 18 military installations and all four branches of the military, along with over 230,000 mostly older military veterans (HRMFFA, 2019). This conglomerate of assets provides value for stakeholders ranging from tourist industries to older veterans and retirees, with the latter requiring additional specialized services such as transportation assistance and specialized medical equipment (Behr & Diaz, 2013). To support populations that require additional accommodations whilst dealing with more flooding, Hampton Roads will need to implement effective adaptation and disaster risk reduction planning and procedures.

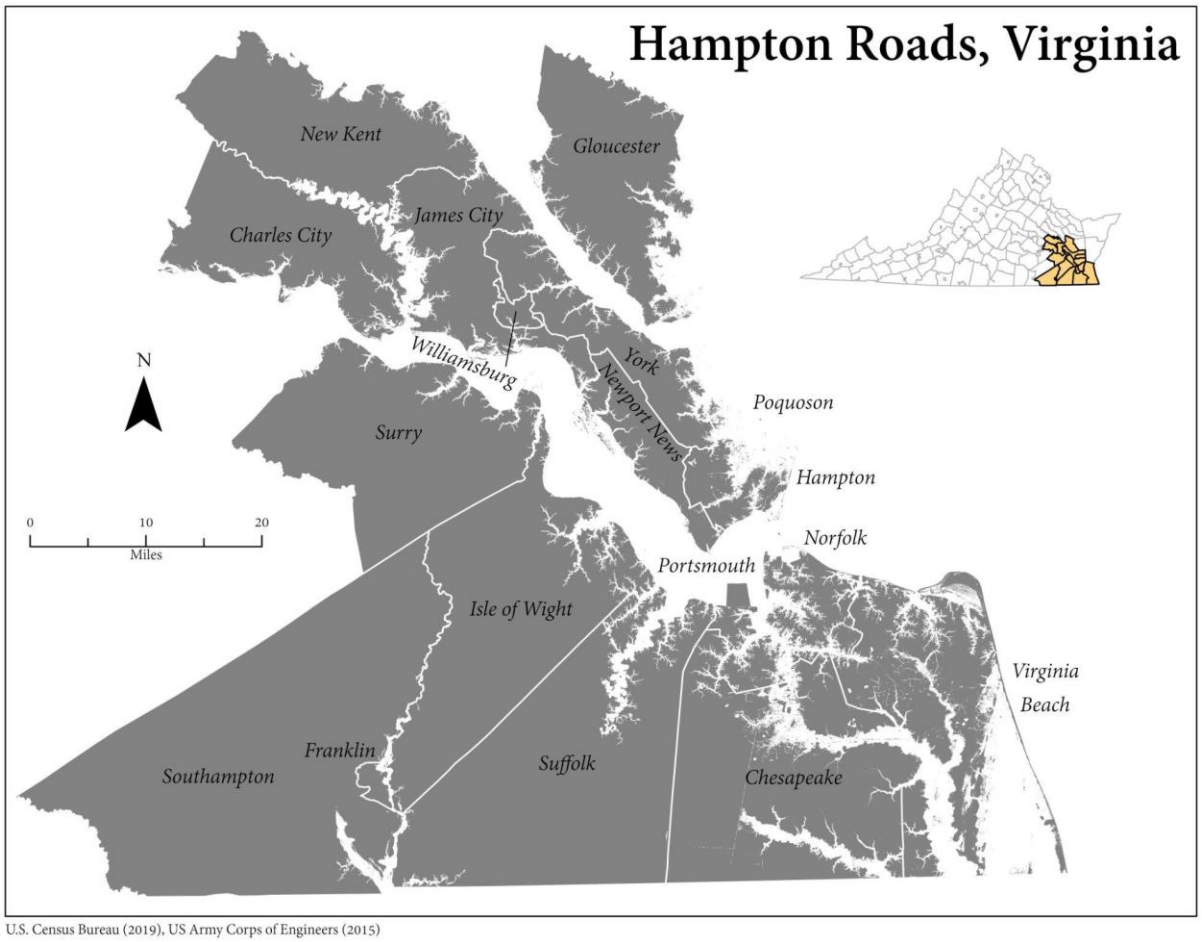

Figure 1. Hampton Roads Municipalities

Older Populations. To assess the exposure to coastal flooding of older populations living in urban areas in Hampton Roads, a geospatial analysis was conducted using the 2019 American Community Survey (ACS) table B01001 Block Group level data filtered for ages 60 and over. The ACS data were used to map the distributions of older populations as a proportion of the total population in each block group. Bins for each percentage were calculated using Jenks Natural Breaks in ArcGIS Pro 10.6.

Inundation Corridors. The estimates for inundation corridors in this study were obtained from Mitchell et al. (2022) and are based on the 2% annual exceedance probability (AEP) hurricane flood hazard, represented by the U.S. Army Corps of Engineers (2015) North Atlantic Coast Comprehensive Study's statistical coastal flood hazard data (NACCS; Cialone et al. 2015, Nadal-Caraballo et al. 2015). These are areas that would be flooded under certain SLR scenarios. The 2% AEP hurricane flood elevations were projected for the base year (2000), and the SLR scenarios in the years 2030 and 2060. These scenarios are based on the intermediate projections for SLR from NOAA (Sweet et al. 2017) that predict a 0.3 m of SLR increase in 2030 and 0.7m in 2060. The intermediate estimates were used as they are more relevant to policymaking. The SLR corridors in the NACCS study provided depth and no depth scenarios for each year. For the sake of simplicity

in our study, we used the no-depth scenarios, which assume a constant flood depth over the entire space.

Mean Calculation. The spatial extent of storm surge flood corridors was analyzed in ArcGIS Pro version 10.6. Eleven block groups were excluded from this analysis because they were uninhabited, and the percentages for the area exposed to flooding and for older populations were calculated for the remaining 1,158 block groups. First, each inundation raster was reclassified to assign all values within the raster to either 0 (no data) or 1. The zonal statistics as table tool was used to calculate the percentage of each block group's area that was covered by the flood raster layer. This process was repeated for 2000, 2030, and 2060, and three maps were created to visualize the results from the zonal statistics tool. We also calculated the mean area of flood extent coverage for all block groups within the entire study area for all three years and used these numbers as a baseline for the analysis. Exposed land percentages were categorized based on methods by Mitchell et al. (2022), by creating three bins of equal distributions (≤33%, 66%, and 100%). These bins represent the percent of land predicted to be exposed to flooding in each block group. Both variables (flooding and population age 60 and over) were categorized using the Jenks Natural Breaks method. The proportion of older adults as a part of the total population was visualized for each block group. Finally, we mapped the block groups in 2000, 2030, and 2060 that were above the mean flood extent and older proportion percentages and overlaid them to create a composite map for 2000, 2030, and 2060. These maps were supplemented by scatter plots to better analyze patterns in changes in both flooding and age variables. This method treats flooding as a binary and assumes no change in coastal morphology over the studied periods. Block groups were selected as the unit of analysis because they provide a large enough scale to differentiate and classify sections within the administrative boundaries with different physical characteristics like slope and elevation that affect flood risk. It is important to note that this study does not address population changes, which would be difficult to model due to changing aging patterns and overall uncertainty (Urban Institute, n.d.). Therefore, our study treats percentages of older populations as constant throughout the study years.

***Survey analysis*.** The primary data used in this analysis were obtained and aggregated from two surveys on attitudes towards relocation among urban coastal residents. The first survey was administered to rural locations on the Eastern Shore, Maryland, and urban Hampton Roads municipalities (Virginia Beach, Norfolk, Portsmouth, and Hampton), Virginia, in August 2019. The respondents were selected from the random sample of homeowners residing in the coastal corridors exposed to the storm surge adjusted for the sea level rise projected for 2090 (Mitchell et al. 2022). The survey had 18 qualitative questions and two open-ended questions assessing past exposure to flooding, reasons for considering relocation, willingness to relocate, and considerations for selecting the receiving location (Bukvic & Zobel, 2022). The second survey was conducted in identical rural and urban coastal locations prone to flooding via telephone in March 2021. The respondents were recruited from the selected flood-prone areas and asked to complete the survey with 20 quantitative questions (Bukvic & Barnett, 2021).

These data were first prepared by identifying and extracting all responses from respondents over the age of 60. From this subset of survey responses, urban zip codes for Hampton Roads were identified and extracted. This process resulted in a final sample of 72 surveys to be included in the statistical analysis. Considering not all questions were the same between these two surveys, the

responses were further screened to ensure the question and answer formats align. Some questions had to be omitted, such as a question about the importance of the community's layout that was only included in the telephone survey. Some answer choices had to be reorganized and converted into a standard binary or ordinal format. This screening process produced a final table of questions and answers that were consistent between both surveys.

To understand what factors are influencing respondents' willingness to relocate, the survey data were first assessed using descriptive statistics and then analyzed for nonparametric correlation using Spearman's rho pairwise correlation analysis in JMP Pro 16. A correlation analysis was chosen over other statistical methods because of the distribution and type of survey data being analyzed. To run the correlation, survey responses were sorted into five categories: Place attachment, community importance, flood experience, relocation opinions, and sociodemographic characteristics. Questions from each category were tested against the question asking if respondents would be willing to relocate due to flooding. Responses for this question were originally formatted with four choices (Yes, No, Maybe, Don't Know) and were converted to a binary scale combining No, Maybe, and Don't Know into No. This was done to create a clear distinction between explicit Yes answers and all other answers. Our dependent variable in this analysis was the question that asked if residents would be willing to consider relocation, and our independent variables were all other questions.

2.3 Results

Exposure of older populations to storm surge flooding. Hampton Roads has a higher fraction of the population over the age of 60 than the United States as a whole (21% vs. 16%). **Figure 2** shows the percentage of each block group that is or will be exposed to flooding for each selected year (A-C), and the proportion of older adults as a percentage of the total population in Hampton Roads in 2019 (D). While flood extent percentages are relatively low in rural municipalities, both rural counties in Hampton Roads (Southampton and Franklin City) have high percentages of older residents. Specifically, Southampton has more than 32% of its population over 60. All the block groups in New Kent have ≤32% older residents, and Charles City has one-third of its block groups in the highest (≤73%) category of older adults as a proportion of the total population. A substantial number of block groups in this region have unusually high percentages of older adults as a proportion of their total population. For example, a block group in Suffolk City has the largest percentage of older adults at 72.8%, reflecting its small total population of 604 and the presence of a large retirement community housing a large majority of the block group's residents. Other high-percentage block groups in this study have similar circumstances explaining their unusually high proportions of older adults.

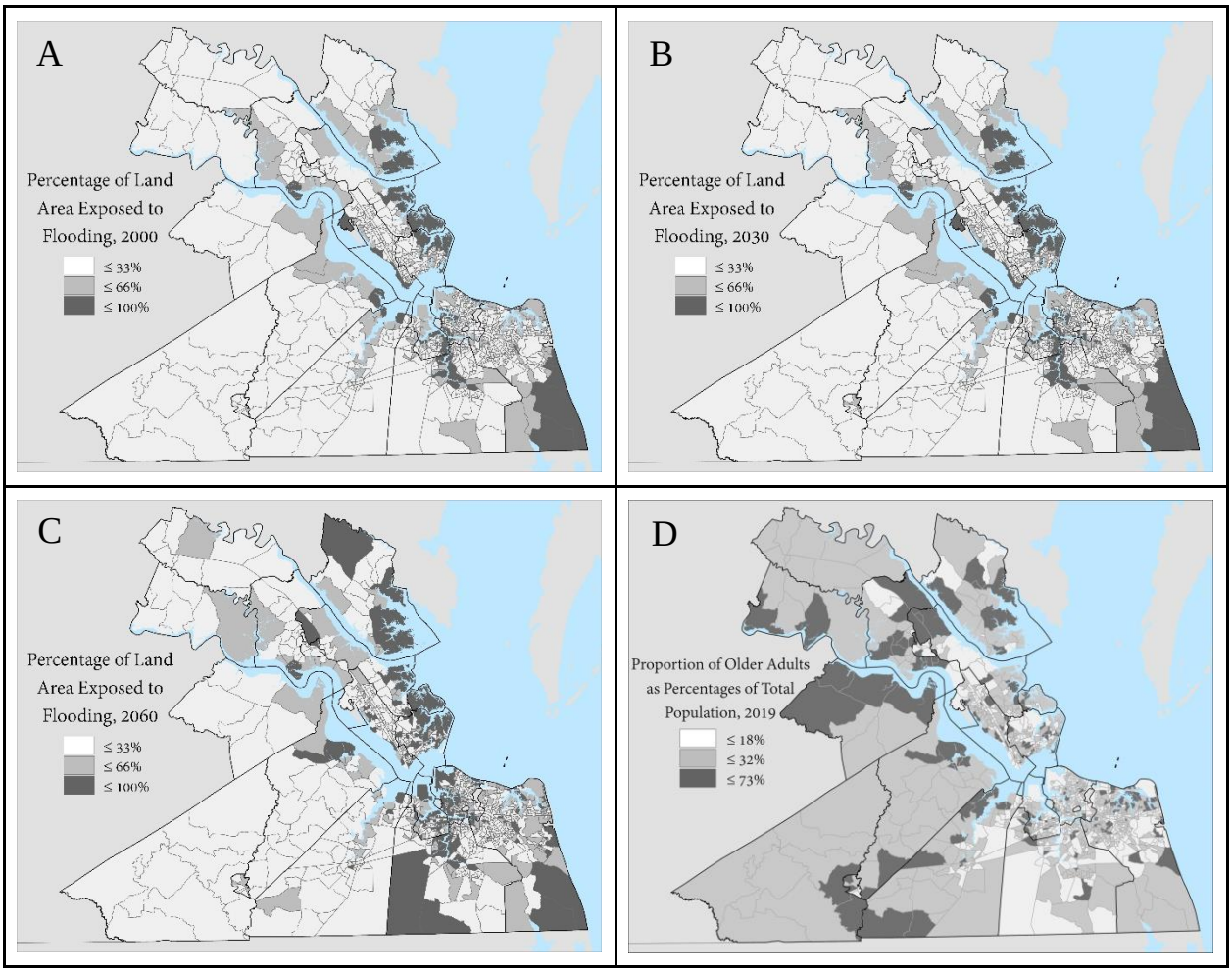

Figure 2. Predicted flood exposure by the percentage of land area covered by flooding in the years 2000, 2030, and 2060 (A-C), and the proportion of older adults as a percentage of the total population in 2019 (D)

Figure 3 demonstrates the spatial correlation between the age 60 and over populations and flood risk in Hampton Roads, highlighting the block groups with above-average percentages of older populations and flood extent coverage in Hampton Roads in 2000. Each point in the scatter plot represents one high-risk block group. The chart shows that 230 out of 1,158 block groups have above-average means for both variables, and can be considered high-risk locations where flood and age vulnerability risks converge. The average percentage of flood extent area per block group in the whole region for 2000 is 20%. The distribution of flood extent is relatively uniform, with a cluster around 20% flood extent, and a low density of block groups past 50% extent. The highest concentration of flood extent in 2000 is 55% and below. **Table 1** shows the average exposed area for all block groups in each municipality and the number of block groups in each municipality that are considered high-risk. Virginia Beach has the most block groups (51) in this category. Three municipalities only have one high-risk block group, two of which are rural municipalities: Southampton and Franklin City. Compared to the urban municipalities, they also have a low mean flood extent percentage (26.65, 32.96%). For the 2000 scenario, Poquoson has an average flood extent percentage of 94.28%, suggesting that the majority of its land area is somehow impacted by

water. This could mean that this region is already experiencing flood impacts and could have more adaptation measures in place, but should be analyzed on a more granular scale to understand specific policies, neighborhood dynamics, and infrastructure patterns.

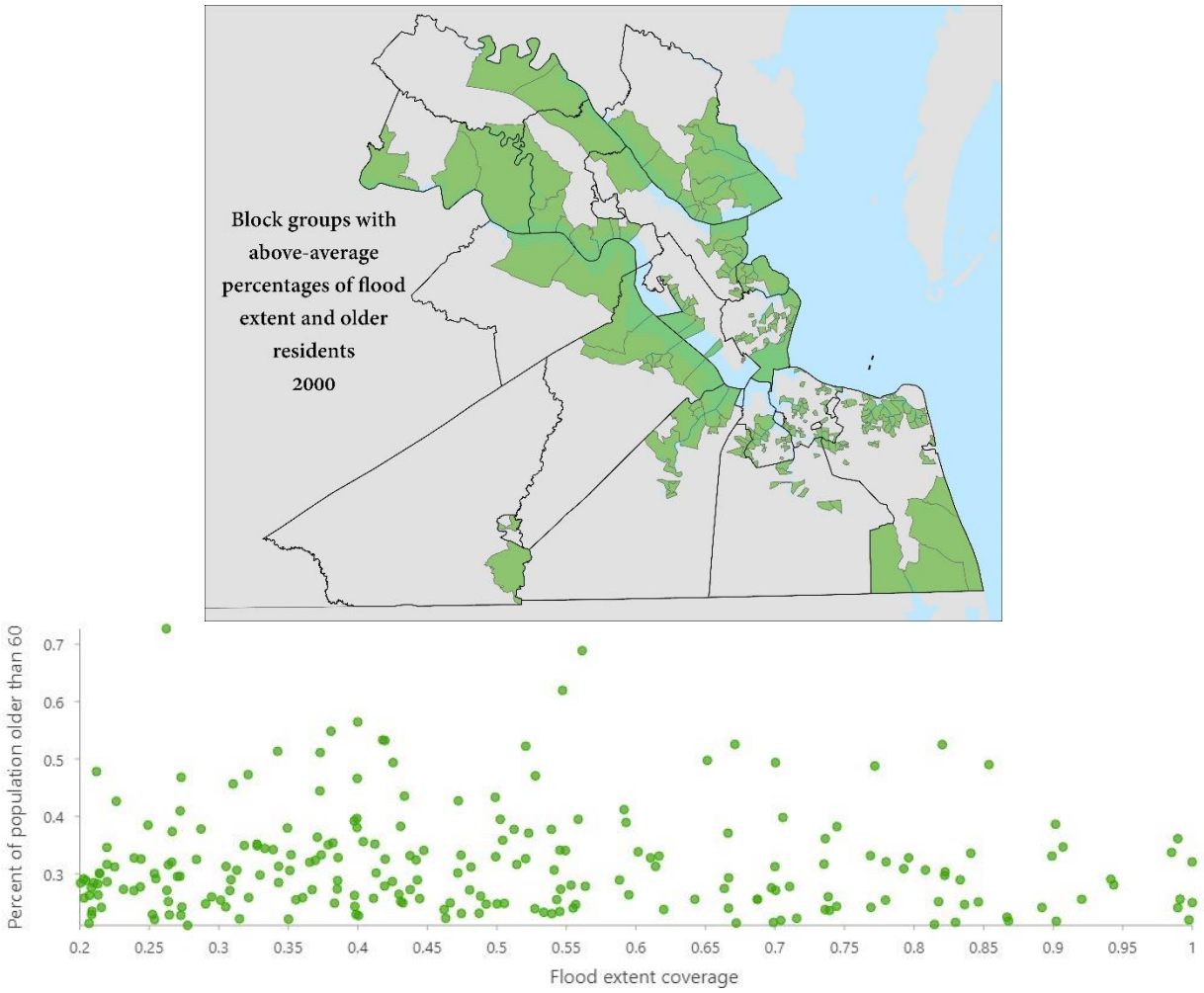

Figure 3. High-risk block groups (figure above) and **s**catter plot (below) showing the distribution of block groups by flood extent and percent of older populations (60 and over) in 2000

Table 1. The average percentage of flood extent and number of high-risk block groups in Hampton Roads in 2000

Boundary	*Mean Percent Flooding*	*High-risk Block Groups*
Poquoson City	94.28%	7
James City County	42.40%	9
Surry County	35.58%	2
Gloucester County	63.19%	12
Chesapeake City	52.36%	14
Isle of Wight County	50.62%	8
Franklin City	32.96%	1
New Kent County	27.22%	3
Charles City County	24.95%	3
Newport News City	70.46%	12
Portsmouth City	47.99%	20
Norfolk City	53.53%	38
Williamsburg City	20.01%	1
Southampton County	26.65%	1
Suffolk City	48.01%	14
York County	53.33%	14
Hampton City	83.19%	25
Virginia Beach City	64.85%	51

In 2030, the overall average flood extent threshold area for Hampton Roads will increase to 24%, representing a 20% increase from 2000. Accordingly, three more block groups could fall into the high-risk category between 2000 and 2030, making the total number of block groups in this category 233. The distribution of above-average flood extent block groups in 2030 is similar to 2000, but clusters of block groups increase from 20% to 30% and 45%, suggesting that flooding will increase overall flood extent in Hampton Roads **(Figure 4).** Franklin City and Southampton still have one high-risk block group, while most of the urban municipalities have significantly more. Virginia Beach is predicted to have the highest total number of high-risk block groups (n=50) based on the flood extent for 2030, and the mean flood coverage could increase by 4% by 2030. Hampton City will have a high (85.95%) average flood extent percentage, and a significant number of block groups (n=29) in this high-risk category, but is predicted to experience an increase in flood exposure only by 2%. Poquoson could see an increase of almost 4% in exposed areas, which could increase this municipality's average block group flood exposure levels to 98.22%. Within the next eight years, the scenario for 2030 in this community could happen, which is likely within the lifetime of many older residents. Therefore, it is important to communicate these near-future scenario results to community leaders so they can emphasize the impending flood possibilities and accompanying adaptation measures like relocation.

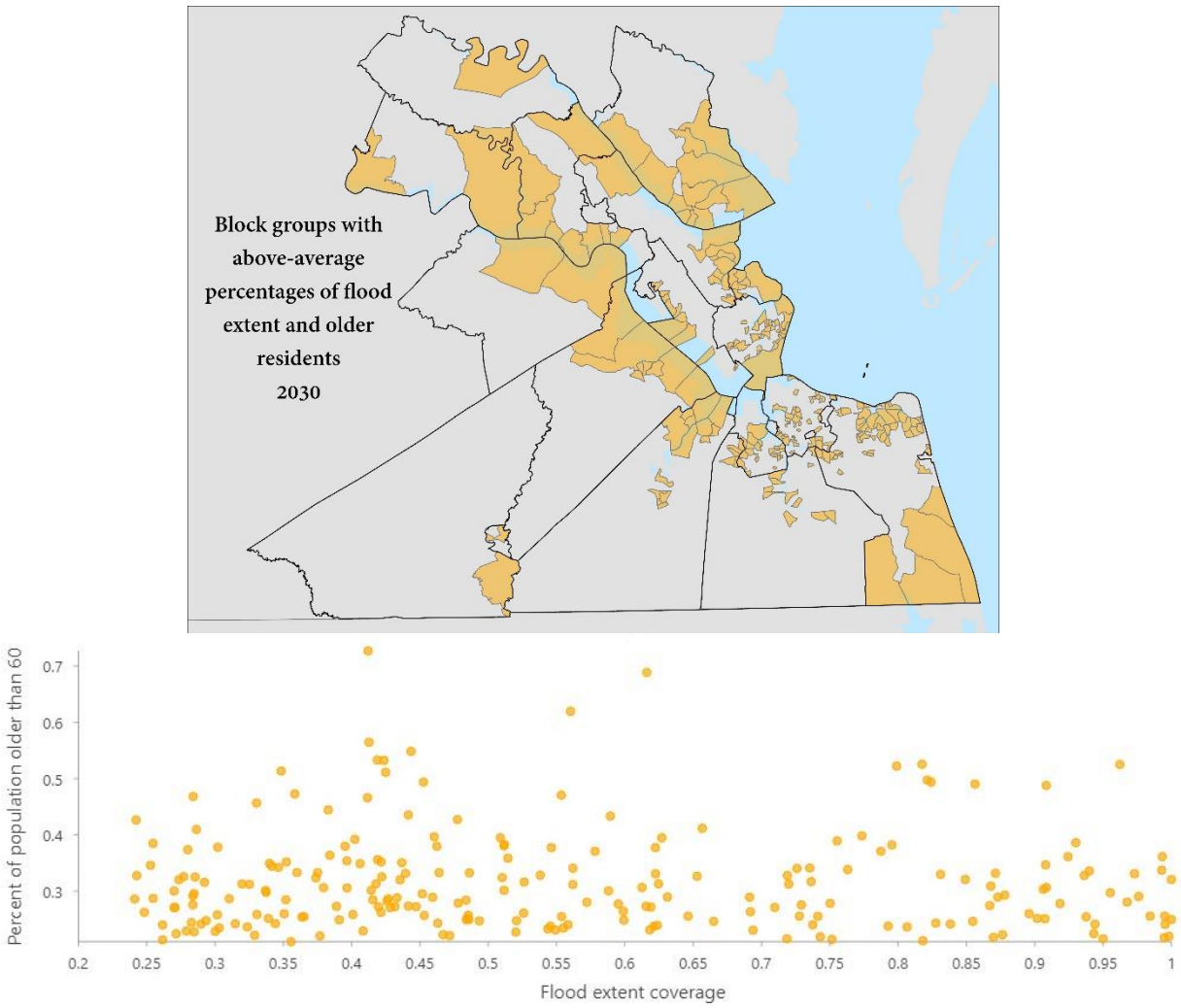

Figure 4. High-risk block groups (figure above) and **s**catter plot (below) showing the distribution of block groups by flood extent and percent of older populations (60 and over) in 2030

Table 2. The average percentage of flood extent and number of high-risk block groups in Hampton Roads in 2030

Boundary	*Mean Percent Flooding*	*Number of Block Groups*
Poquoson City	98.22%	7
James City County	43.19%	9
Surry County	35.78%	2
Gloucester County	66.72%	12
Chesapeake City	52.84%	16
Isle of Wight County	50.87%	8
Franklin City	33.74%	1
New Kent County	31.97%	2
Charles City County	26.83%	2
Newport News City	72.60%	11
Portsmouth City	54.37%	21
Norfolk City	62.31%	40
Williamsburg City	0.00%	0
Southampton County	28.01%	1
Suffolk City	56.08%	13
York County	56.69%	13
Hampton City	85.95%	29
Virginia Beach City	69.27%	50

Flooding risk will increase substantially by 2060. The average flood extent area in each block group in 2060 could increase to 31%, an almost 23% increase compared to 2030, with 235 block groups falling within this high-risk category **(Figure 5**). The scatter plot visualizes how the high-risk block group flooding in 2060 is more concentrated than the years before, with several block groups clustered around 50-60% and 95-100% exposure levels. There are 48 block groups in the 95-100% exposure category, all of which are in urban counties. Norfolk has the most (n=13), followed by Hampton City (n=9) and Poquoson and Portsmouth (n=7). Norfolk is of particular interest because this municipality also has the potential to experience a 12% increase in mean flood extent area for 42 block groups. This clustering pattern was not present in 2030 and shows a substantial increase in plausible flood extent. If this many block groups become exposed to storm surge flooding toward 2060, thousands of people are likely to be affected. Additional physical and social systems are likely to be impacted, especially if they did not have adaptive measures put in place to deal with such an increase in flooding. The trends in predicted flood extent between all three time periods are not linear, with higher levels of change happening between 2030 and 2090 than between 2000 and 2030. This is a significant finding because while flooding in the first 30 years may not seem significant and residents may be less concerned about flood impacts, it will rapidly accelerate possibly finding many communities unprepared for rapid changes in the extent and severity of impacts.

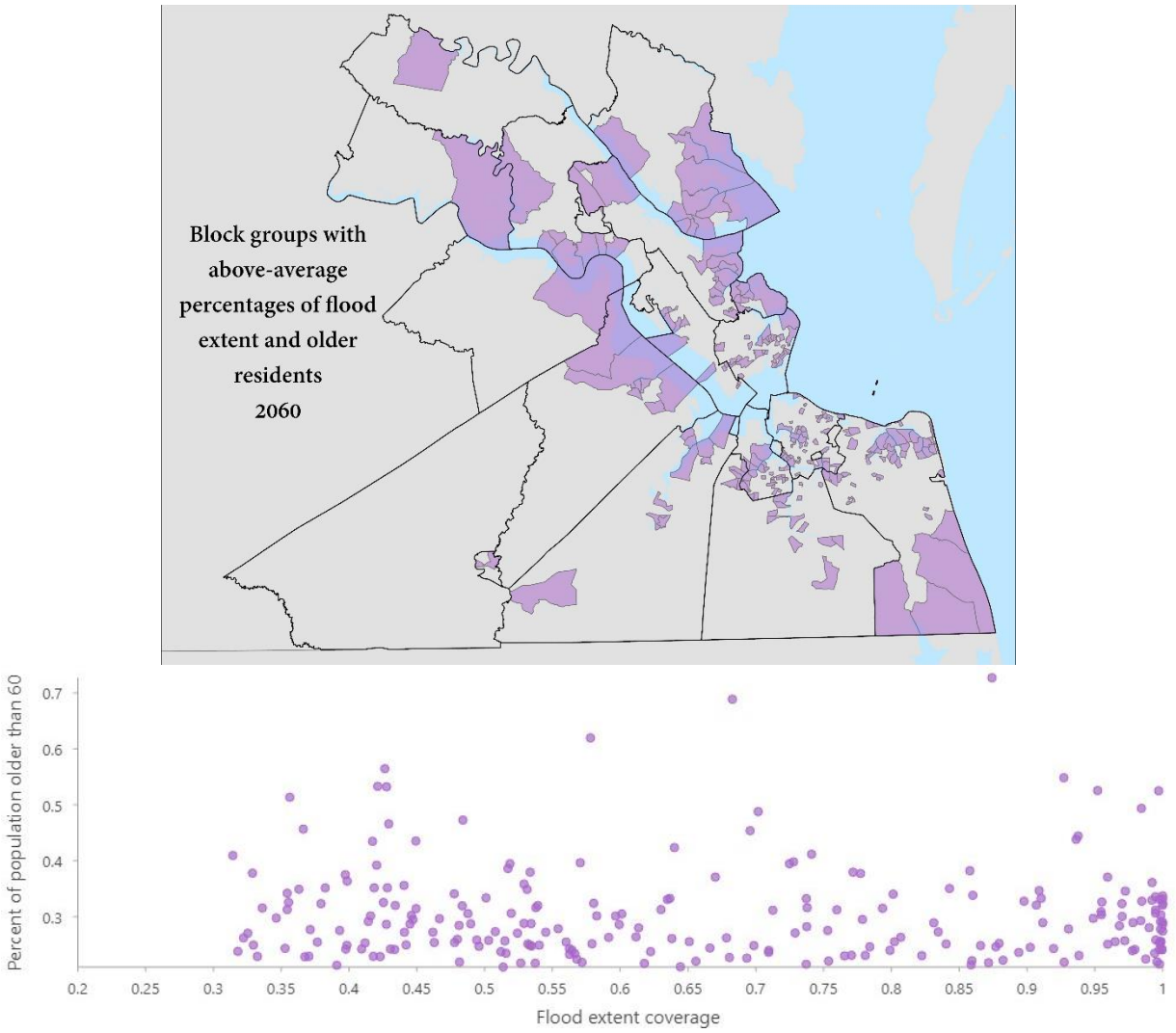

Figure 5. High-risk block groups (figure above) and **s**catter plot (below) showing the distribution of block groups by flood extent and percent of older populations (60 and over) in 2060

Table 3. The average percentage of flood extent and number of high-risk block groups in Hampton Roads in 2060

Boundary	*Mean Percent Flooding*	*Number of Block Groups*
Poquoson City	99.48%	7
James City County	53.32%	9
Surry County	42.55%	1
Gloucester County	72.96%	11
Chesapeake City	58.93%	18
Isle of Wight County	67.71%	7
Franklin City	34.64%	1
New Kent County	48.98%	1
Charles City County	43.41%	1
Newport News City	82.31%	11
Portsmouth City	64.95%	27
Norfolk City	74.33%	42
Williamsburg City	98.54%	1
Southampton County	0.00%	0
Suffolk City	48.50%	10
York County	67.33%	15
Hampton City	88.76%	29
Virginia Beach City	73.00%	49

Figure 6 shows the overlap of block groups with higher percentages of older adults and flood extent for the years 2000-2060 on a multivariate scale. Isle of Wight has no block groups in the lowest population category and also experiences a 17% increase in mean flood extent area from 2000-2060, which is a notable finding that shows an overlap of areas with more older residents and flood extent that will increase. Surry county has most of its block groups in the highest population category, but only one block group in the highest overlap category in 2060. Other municipalities in this region have less concentrated proportions of older populations, but several have high flood extent increases. Virginia Beach, for example, has the highest number (n=49) of high-risk block groups throughout 2000-2060 and experiences an almost 9% increase in average flood extent area in these block groups. Poquoson will experience a 5% increase in flood extent during this time frame and could see its mean flood extent increase to almost 100%. Hampton City has an extremely high (83.19%) average flood extent area for 25 block groups in 2000, a number that could increase to almost 89% for 29 block groups by 2060. York county has 23 block groups out of 38 with the proportion of older adults over 32%. This municipality is likely to experience a 3% increase in average flooded area for 13 block groups between 2000-2030, with an 11% increase for 15 block groups by 2060, noting a possibly significant overlap of flood exposure and areas with older populations. Overall, there are several increases in the overlap between areas with older populations and flood extent that were predicted from this analysis. Counties like Isle of Wight, Portsmouth, Virginia Beach, and Hampton have several block groups which could move into the highest overlap category by 2060.

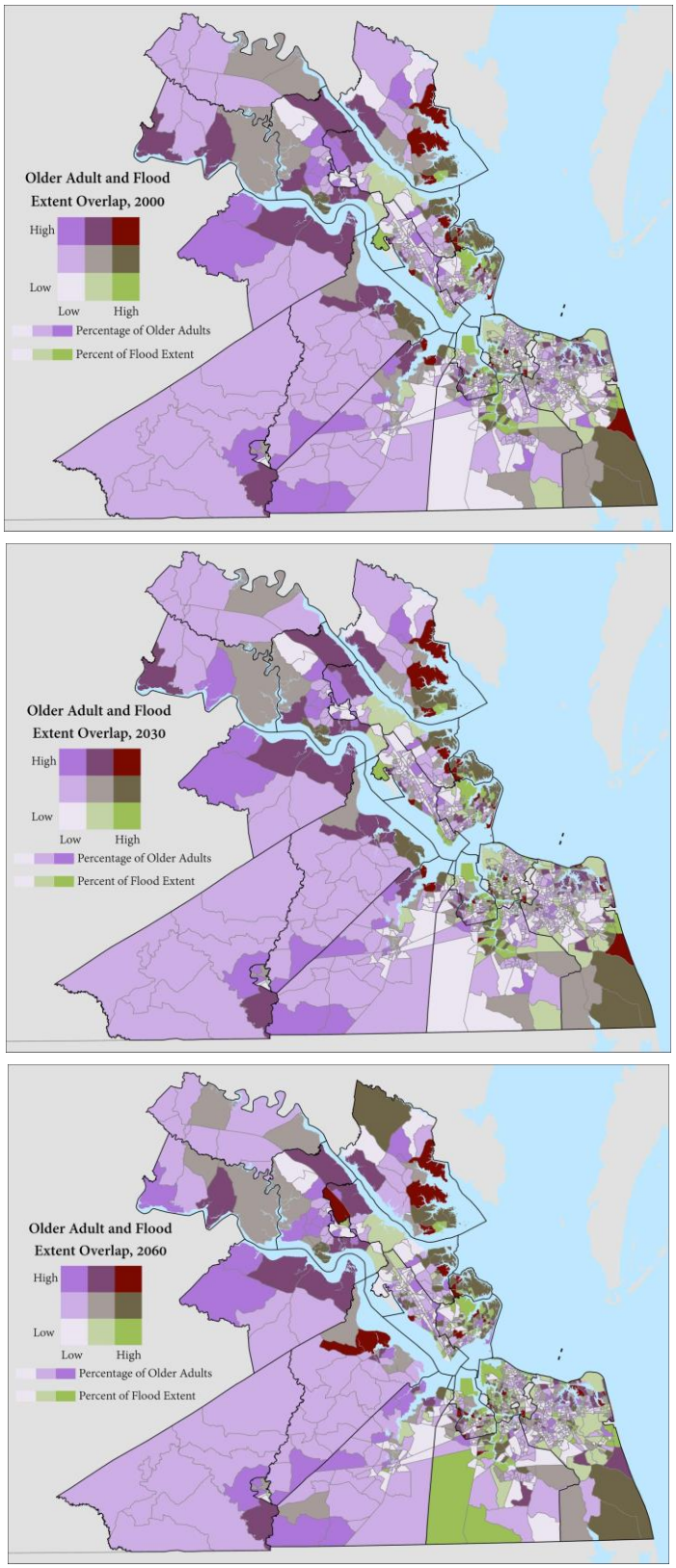

Figure 6. Exposure and age overlap, 2000 - 2060

Statistical analysis. The survey measured the following demographic variables: age (≥60), race, the highest level of education, family structure, income, ownership status (rent or own), and length of residence in the community (Figure 7). Among 72 respondents, 56.94% completed some form of higher education above high school, more than a quarter (27.78%) of respondents make $50-75,000, and 29.17% make $100,000 or more. A vast majority of respondents were long-term residents of the community, with 37.5% living in the area for more than 30 years. This suggests that residents may have built long-standing ties to their community and could be more likely to feel attached to their homes and places. Over two-thirds (84.72%) of respondents are white, and such a homogenous racial group could have implications on other survey categories or importance variables. From the survey, 79.16% of respondents own a house as opposed to renting one which could imply that the process of acquiring resources needed to sell houses may act as a roadblock to relocating. The correlation analysis did not reveal any significant correlations between sociodemographic variables and the willingness to relocate question (Appendix).

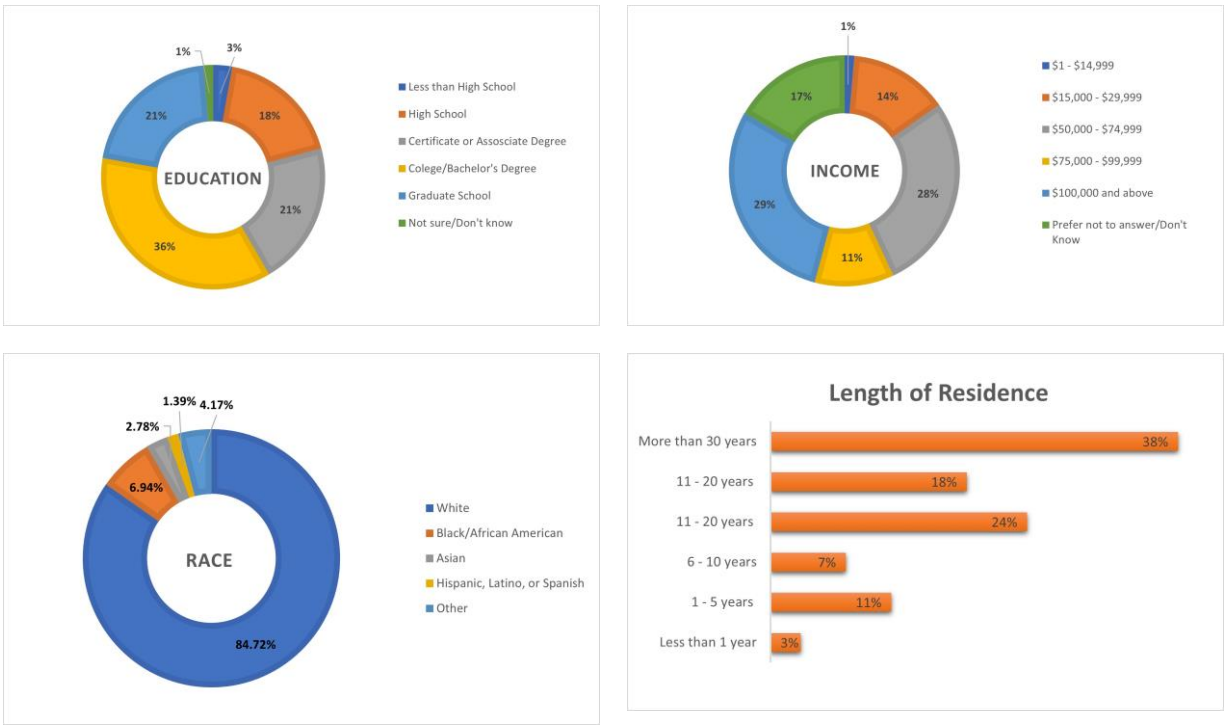

Figure 7. Sociodemographic profile of survey respondents age 60 and over

When asked if they would consider permanent relocation should the flooding in their community become more frequent and severe, 63.89% of respondents said no, and only 36.11% of respondents said yes. The survey also asked questions regarding place attachment based on varying community characteristics (**Figure 8**). Understanding place attachment and its implications on relocation decisions is an integral part of this study. Strong levels of attachment to a respondent's previous location have the potential to negatively impact their psychosocial adjustment and adaptation to their relocation destination (Zhang & Wang, 2020). Additionally, residents who are highly attached to their community are, in many cases, less likely to engage in relocation (Bonaiuto et al. 2016). Overall, there is a smaller (4-15%) percentage of respondents who strongly agree that

certain variables make them feel attached than the percentage (18-25%) of variables that make respondents strongly disagree about the same variables. More than half (51.39%) of respondents agree or strongly agree that they feel attached to their community because of the presence of social and recreational features, which could imply that older residents value social connections with other community members, contributing to their attachment. Combined with the high (18-36%) percentage of neutral responses, respondents generally seem impartial towards their community attachment variables. This falls in line with the correlation results from this section, where several place attachment variables were significantly correlated with each other, but not with a willingness to relocate. The only variable that had a significant correlation (p=.046) with the relocation question from this section was feeling community attachment because of "None or very few hazardous weather events or natural disasters." This suggests that respondents who feel strongly attached to this community because of the lack of hazardous weather events are also more willing to relocate than those who do not feel attached because of the lack of hazardous weather. This is a notable correlation that could account for the contextually high (45.84%) percentages of Agree answers in the survey.

For 60% of the place attachment variables, Neutral was the most selected answer choice. Of these six variables, having a well-established, long-standing community had the highest (36.11%) percentage of Neutral answers, and over 30% disagreed that this variable makes them feel attached to their community. This response is interesting given that over half of the respondents have lived in the community for over 10 years, and 38% have lived there for over 30 years. Perhaps as this community has grown in population (Greater Hampton Roads, 2021), and as flooding has increased (NOAA, n.d.), residents have noticed the community identity disappearing. Overall, the seeming apathetic attachment to the community in these respondents could mean that residents would not be as opposed to relocating, considering that strong attachment often warrants resistance to relocation (Bonaiuto et al. 2016).

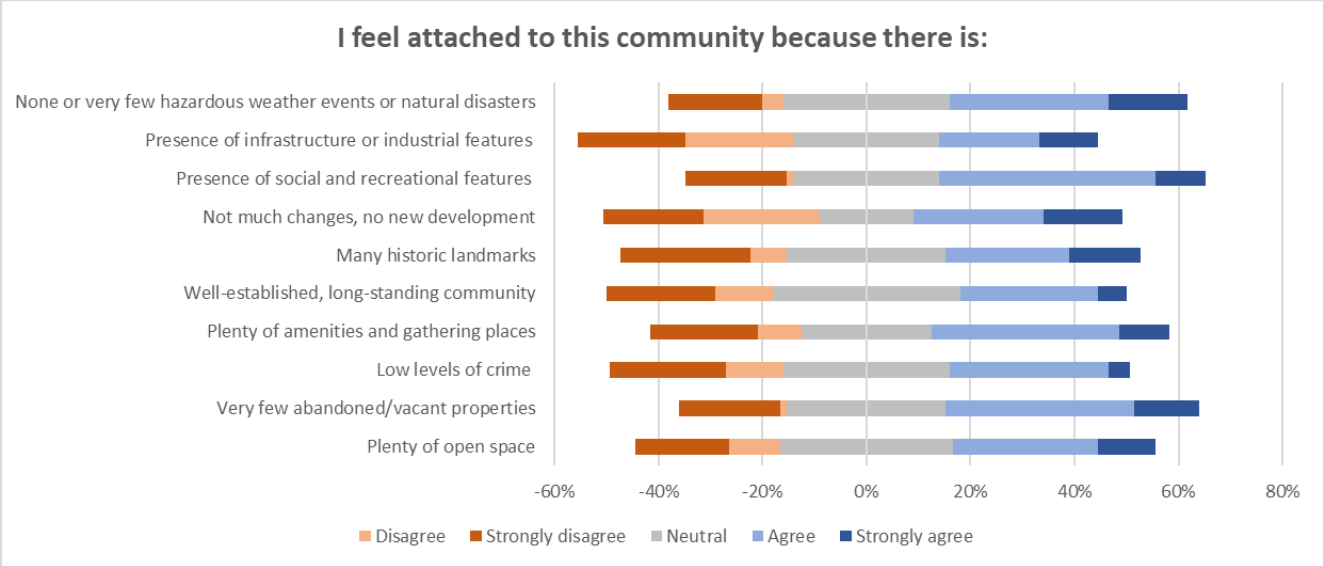

Figure 8. Community attachment characteristics among older adults in Hampton Roads

Figure 9 shows responses to the survey question measuring which variables make living in the community important. Here, 38.89% of respondents agree in some form that attending church and other local organizations is important to them. These types of connections to community organizations could be barriers to older adults' willingness to relocate, given there are likely strong ties within such communities. Over half (51.38%) of respondents agreed that having amenities they need close to where they are is important, likely because many of them utilize age-related health and other amenities. Understanding the suggested importance of such amenities can help policymakers to focus their efforts on ensuring these amenities are also offered in receiving locations. Variables of lesser importance include having the same ethnic group, friends, or family in the community, along with proximity to the beach and ocean. These variables had high (37-38%) levels of neutral responses, which could mean that these characteristics are less important to older residents and may not be addressed in relocation planning. Overall, more than half (66%) of the variables had Neutral as their highest selected choice. This suggests that residents may not be extremely concerned or connected with the factors that make their community feel important - which could impact their willingness to relocate in similar ways as the place attachment variables. None of the community importance variables had a significant correlation with the relocation question (Appendix).

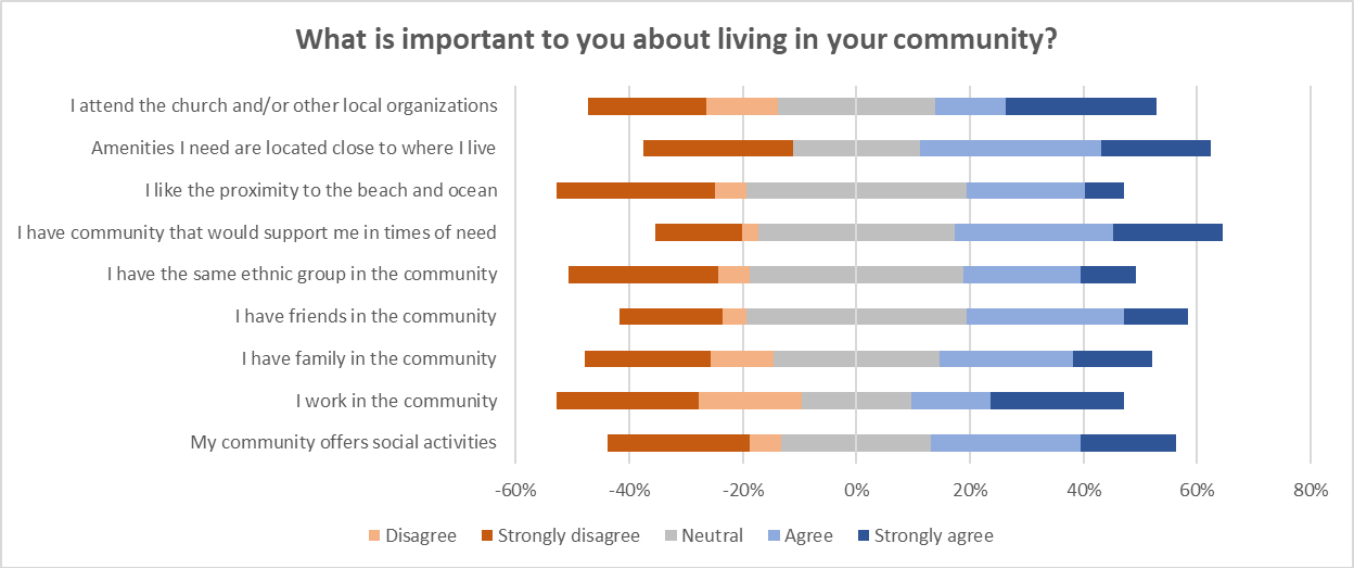

Figure 9. Factors that influence community importance for older adults in Hampton Roads

To understand the respondents' experiences with different types of flooding, the survey asked if they had experienced any of the following types of flooding: sunny day, nuisance, tidal or storm surge, rainfall, or extreme rain event flooding (**Table 4**). At least 40% of respondents experienced each type of flooding: sunny day, nuisance, or tidal flooding (40.28%), storm surge during storm events (44.44%), and rainfall or extreme rain events (41.67%). Almost half (48.61%) of respondents did not experience sunny day, nuisance, or tidal flooding, and less than 37% of respondents did not experience the other two types. The correlation analysis revealed strong, significant correlations among each type of flooding experienced, but no significant correlations between the flood types and the willingness to relocate question (Appendix). The respondents' who experienced one type of flooding also experienced other types of flooding. These results suggest that older respondents are unlikely to have experienced only one type of flooding,

suggesting their residence is prone to overall flooding regardless of the source. Experiencing multiple types of flooding does not support an increase in willingness to relocate, however. Perhaps experiencing these types of flooding events does not mean respondents experienced negative impacts sufficient to prompt them to consider relocating.

Table 4. Types of flooding experienced by older adults in Hampton Roads

Flood Experience	***Yes***	***No***	***Maybe***
Sunny day, nuisance, tidal	40.28%	48.61%	11.11%
Storm surge during storm events	44.44%	36.11%	19.44%
Rainfall or extreme rain events	42.00%	33.00%	25.00%

Respondents were also asked to rank their risk to flooding as it relates to experience or potential future damages to personal property such as a car or home, disruptions to driving or commuting, or health impacts (**Table 5**). Almost half (47.22%) of respondents reported a Low risk, and more than three quarters (80.55%) were Extremely Low or Low risk. Only 19.44% of respondents listed either Medium, High, or Extremely High personal risk to flooding. The correlation between this question and the dependent variable did not reveal any significance, nor did a correlation analysis between types of flooding experienced, personal risk rank, or relocation considerations (Appendix). The fact that none of these variables correlated suggests that there is a disconnect between the flood experience and personal risk perceptions. Further analysis that might provide additional insights would be a proximity assessment to identify whether respondents living close to the ocean think differently about relocation than those who live further inland. Since Bukvic et al. (2018) found that people who live closer to hazards generally have higher levels of concern for their vulnerability to those hazards, this type of analysis would benefit our study and could explain some of the variation and disconnect in answers.

Table 5. Surveyed adults' ranking of personal flood risk

Personal Flood Risk	
Extremely Low	33.33%
Low	47.22%
Medium	6.94%
High	6.94%
Extremely High	5.56%

Respondents were also asked what impacts they experienced from flooding, shown in **Figure 10**. Almost 60% of respondents have not experienced any of the listed flood impacts, which may have implications on their decision to relocate. While a large percentage of respondents have not experienced any of the listed impacts, there are some significant findings indicating the type of key flood experiences. Almost half of the respondents (47.22%) have experienced canceled doctor and other appointments and damage to personal vehicles, two impacts that may have consequential effects on this population which is likely to require more frequent medical attention/transportation

to health facilities. The correlation analysis revealed strong significant positive correlations between the majority of these answer choices, when one impact was experienced, another one was likely to also be experienced. (Appendix). Considering flooding and relocation can exacerbate preexisting vulnerabilities in older adults (Bukvic et al. 2018; Farbotko et al. 2020), this population may be reluctant to risk any unnecessary disruptions and consequences, especially if they have not experienced many significant flood impacts. Residents must understand how the flood risk will propagate in the future, and make an informed decision about their vulnerabilities before the disaster strikes. This type of preparedness is what Castle (2001) cited as lending to effective relocation strategies which avoid unnecessary stress and harm.

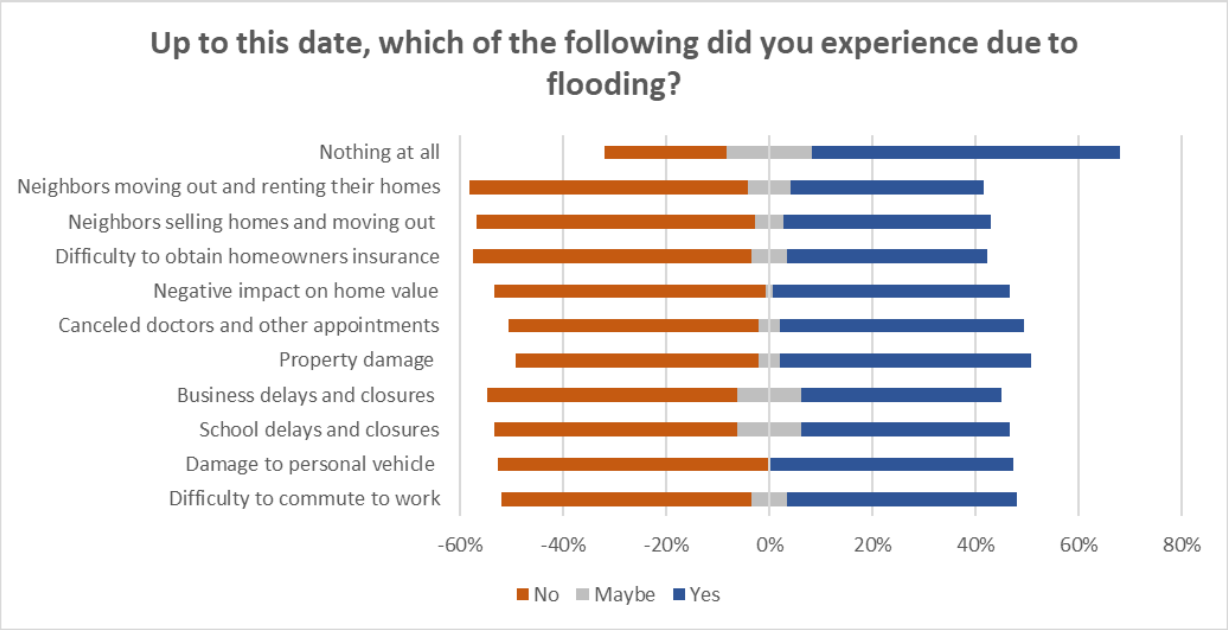

Figure 10. Flood impacts experienced by surveyed populations

The last section of the survey measured considerations that would prompt respondents to permanently relocate due to flooding (**Figure 11**). The two variables with the highest percentage of Strongly agree responses pertain to some sort of outside assistance for relocation. Receiving assistance finding a new job elsewhere was the highest (33.33%) Strongly agree choice, and being provided free legal advice for relocation options was the second highest (29.17%). This relates to findings from Castle (2001), where effective relocation planning that involves older adults and allows them to maintain a sense of control in their relocation improves their overall health and morale by avoiding negative consequences of relocation like shock or depression. This also coincides with findings from Bukvic et al. (2015), which found that economic factors played an important role in support for relocation among coastal residents. Being offered financial compensation (buyout) had a significant positive correlation with the willingness to relocate, meaning that respondents offered financial compensation (buyout) are also more likely to relocate. Further, over 50% of respondents agreed in some capacity they would consider relocation if they cannot access amenities or services, which makes sense given that older adults often require regular access to health amenities and emergency services (Behr & Diaz, 2013).

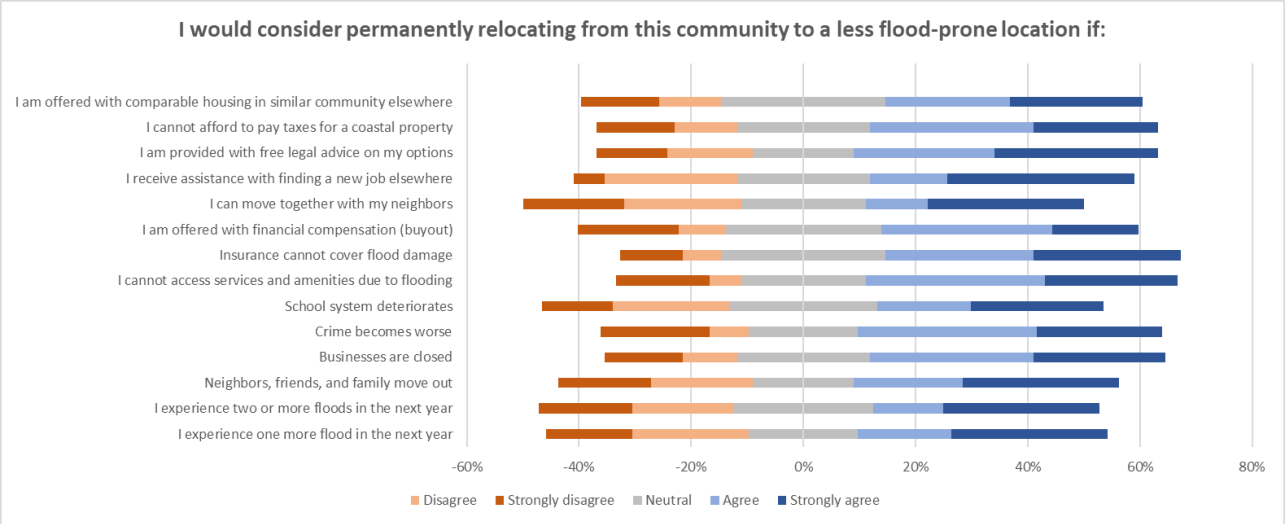

Figure 11. Relocation considerations among survey respondents

From **Table 6**, when asked where they would prefer to relocate, 25% of respondents said they would move to a different state, such as Florida, Tennessee, North Carolina, Georgia, and Massachusetts. These choices are all on the eastern portion of the United States, and four out of five are coastal states, suggesting that respondents enjoy living on the coast, but are not necessarily tied to Hampton Roads. However, this also means that some of those states could have the same if not higher flood risk in coming years. This highlights the need for accurate and explicit information detailing flood risks and impacts in coastal regions, especially ones where older adults tend to move. Perhaps residents are polarized on their relocation destination options, and they are either willing to relocate very short distances (a neighborhood or a community), or very far distances (a region or a state), but unwilling to move distances in between such as county (2.78%). This may be because residents want to either a) move from flood zones but stay close to amenities or facilities they are familiar with, or b) move farther away for various reasons like being closer to family members or a more supportive care system, or to avoid increased crime or traffic.

Table 6. Preferred receiving relocation areas of survey respondents

Should I have to relocate due to coastal flooding, I would prefer to move:	
To same neighborhood, but different home	15.28%
To same community, but different neighborhood	18.06%
To same county	2.78%
To same region	12.50%
To same state	15.28%
To different state	25.00%
Other	11.11%

2.4 Discussion

Flood exposure is a significant threat to coastal communities, especially to socially vulnerable populations. In Hampton Roads specifically, flooding can significantly impact older populations due to their chronic health conditions and medical assistance needs. While several studies have researched the overlap between flood exposure and older populations (Bukvic & Harrald, 2019; Bukvic et al. 2015; Kleinosky et al. 2007), none have explored their attitudes toward relocation as an adaptation response. Our study builds on previous research analyzing flood risk and older populations, and includes a correlation analysis of which factors are more important in determining willingness to consider permanent relocation in Hampton Roads. The main contribution of this research is to provide empirical evidence showing an increase in exposure of older populations to flooding over the next few decades and the potential implications for risk of displacement and relocation among this vulnerable group. Additionally, our research can inform policy meant to protect flood-prone populations by evaluating risk perception and comparing it to actual risk to highlight discrepancies in flood adaptation policy. Our first major finding is that flooding extent within the Hampton Roads study area is likely to increase significantly, with an overall mean flood extent increasing from 20% to 31% in sixty years. Additionally, the results from our geospatial analysis suggest that flood exposure is likely nonlinear and increasing with time, with several areas in Hampton Roads experiencing more accelerated increases in potential exposure between 2030 and 2060 than in 2000 and 2030. This could have negative implications on residents' perceptions of their flood risks because the impacts they have experienced may not be representative of what is likely to occur in the distant future. If these vulnerable populations are not cognizant or concerned about their flood risk in the future, they are unlikely to influence policymakers to allocate funding or other supportive materials to help protect their communities. Our survey analysis supports this suggestion, where over three-quarters (80.55%) of survey respondents reported having low or extremely low flood risk, despite experiencing several flood-related impacts and living in municipalities with high flood exposure. This finding highlights the dangerous disconnect between actual flood risk and perceived risk, which could have detrimental impacts on physical and mental health when residents do not relocate amidst accelerated flooding in their communities. However, over half of survey respondents had not experienced any type of flood impact at the time of the survey, and Bradford et al. (2012) found that flood risk awareness is strongly correlated with flood experience, which explains why flood risk perception in our study was so low given that flood experiences were also low. This discrepancy highlights the need for collaboration between community members and policymakers. When both groups come together to disseminate information and propose ideas, effective adaptation or relocation strategies that consider community concerns and values can be made. Local governments and policymakers should respond to the observed inclination to relocate should monetary incentives be put in place by implementing incentive programs like buyout or relocation stipends. However, there may be a lack of community consensus surrounding proper mitigation and relocation plans, just as there was no consensus surrounding community importance and attachment variables in Figures 8 and 9. Thus, it is essential to pilot proposed adaptation measures with target community members before implementing them to ensure higher rates of agreement and participation. Additionally, relocation planning should take place well before the proposed exposure increases, as suggested by Castle (2001). When relocation efforts occur before disaster strikes, they are more effective at protecting community members and allowing for sufficient time to mitigate negative relocation impacts (Ferris & Weerasinghe, 2020; Shearer, 2012). Because the preparation of receiving locations with protective factors in neighborhoods and communities can mitigate some harmful relocation effects

(Zhang & Wang 2020), policymakers should use the results from this study to understand their role in aiding healthy relocation for their residents by providing free access to transportation away from flood zones, offering monetary incentives to move, and offering comparable housing situations away from flood zones. However, such relocation planning and funding should not be uniform. Our study, similar to Liu et al. (2015), found that urban areas within Hampton Roads experience more flooding than their rural counterparts. Accordingly, the relocation efforts offered to residents throughout Hampton Roads should be focused on where flooding is and will be of most concern – urban areas. Policymakers should use the results of this study to identify which urban areas should receive the most support based on their overall risk of flooding exposure and their population of older adults. Visualizing risk and disseminating results from this and similar studies to potential residents in coastal areas can be an effective strategy to manage risk perception and allow older residents to make more informed decisions before buying or renting properties in coastal risk zones.

Studies like Bukvic et al. (2015) found that older age has a buffering effect on relocation decision-making, and Prohaska & Peters (2019) and Malik et al. (2018) findings suggest that age plays a significant role in a person's ability to cope with risk due to their age-related health vulnerabilities. Our study produced similar findings as Bukvic et al. (2015), where the variables which elicited the highest percentage of both positive response choices related to some sort of outside accommodation like legal advice, job assistance, or if insurance cannot cover flood damages, and are important relocation drivers. These findings build on the results by Bukvic et al. (2015), but in a different region in a more refined population of older adults. Implementing some sort of community meeting system where community members from all localities can come together to discuss their concerns and understand actual flood risk can be beneficial, considering that community involvement and engagement are essential in relocation planning processes, (Castle, 2001). Using community involvement to understand and support flood adaptation strategies has already been implemented in some municipalities in Hampton Roads. Portsmouth, which, based on our study, will have 27 block groups in high-risk categories of flooding and older population percentages by 2060, is actively engaging its citizens in its flood adaptation planning (Behr et al. 2016). Almost 2,000 surveys were distributed by the local government to help the city understand the flood experiences and perceptions of its residents (Behr et al. 2016). Such community involvement is exactly what our study focused on, except on a larger scale. Following the lead of Portsmouth, other municipalities within Hampton Roads should involve their citizens in their adaptation processes to make sure that needs are being met. While our study found that monetary incentives play an important role in Hampton Roads residents' willingness to relocate, our sample was small, and municipalities should create personalized surveys, like Portsmouth to fully understand the situations of their residents.

The disproportionate health impacts on older populations following natural disasters like flooding present an emerging need for effective accommodations. In the context of this study following relocation, resources and planning to support older adults like ensuring access to health care facilities, and providing monetary support for the acquisition of housing in receiving locations is essential. Policy that enhances community cohesion by encouraging social learning and raising awareness can be an effective strategy to bolster community preparedness (Marshall & Owens, 2014), and should be encouraged in Hampton Roads for those residents who choose to stay amidst increased flooding. However, community adaptations may not protect or encourage residents to

move away from increased flooding in the area, so hard adaptation measures like sea walls or raised buildings may be necessary to protect the residents staying in Hampton Roads. Staying in Hampton Roads amidst increased flooding may be the only option for some older residents. Those with mortgages may not be able to pay off the rest of their balance to move, and those who have paid off may not be able to sell their homes due to increased property taxes or damages due to flooding. Even those residents who can move independently may not have any family or support elsewhere, which is why outside assistance like managed housing programs or financial stipends from policymakers is essential to help encourage those able to leave to pursue relocation.

***2.5 Limitations*.** There are several ways in which this research is limited. First, this study does not account for demographic changes in the percentage of older adults from 2000-2060 because population patterns are constantly changing, and could not be consistent for sixty years (Urban Institute, n.d.). Because coastal areas are preferred retirement areas, Hampton Roads could potentially see an increase in older adults throughout the period in which flood exposure was measured. This impacts the composite results and has implications for the communication of this research. It is also important to note that these calculations are focused on dynamic flood predictions but include static age percentages. As older populations are expected to increase, and possibly retire in coastal areas (Frey, 2003 & Sharma, 2015), the inclusion of predictions in the growth of older populations would make future studies more robust. Additionally, this research assumed a uniform distribution of older populations over the block groups. In reality, there are likely pockets of higher and lower percentages of older adults than the mean produced by this study. This has important implications for the communication of flood risk to certain areas which have higher proportions than others. Also, this study did not analyze the region on a larger scale than block groups, which leaves some questionable results unanswered. For example, in the ~ 5o block groups with more than 50% older adults, it would be beneficial to understand if these areas have high numbers of retirement homes or long-term care facilities. Again, further research should analyze these discrepancies on a closer level. Additionally, flooding in this study was treated as uniform and did not consider depth in our analysis. Some regions of exposed areas could have much higher depths of water inundation, affecting overall exposure calculation.

As Haynes et al. (2008) and Peacock et al. (2005) found, proximity to hazards plays an important role in determining risk perception. In our study, the geospatial results are limited by their scale. Our analysis would have been more useful in understanding how respondents viewed their risk of flooding if we had used a finer-scale neighborhood flooding and survey model. The geospatial analysis in our study relied on a block group scale rather than neighborhood or street level, which could explain the discrepancy between flood risk perception and flood extent. Understanding that people living closer to coasts are more likely to believe in climate change than those farther from the coast (Milfont et al. 2014), our study could be improved by examining the locations of respondents on a parcel level to see if relocation was considered more by residents closer to the flooding. The statistical analysis was mainly limited by sample size. Filtering the survey down to a small number (n=72) of respondents limited the capabilities of statistical tests and interpretation of results. Such a small sample produced correlations that were hardly significant and could have been improved using a larger sample. Additionally, this cohort of respondents was very homogenous by race and age, two factors which likely affected the results of this study.

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3. Conclusions and Summary

Overall, these geospatial results show that there is already a significant overlap in projected storm surge flooding extent with the areas where older residents live in Hampton Roads. Such flooding is not linear, with some areas that could experience higher increases in flood exposure than others. Older residents in Hampton Roads seem unaware of their overall flood risk, with the majority considering themselves at low risk. More respondents answered no or maybe to considering relocation than yes, and only buyout programs and experiencing a few hazardous weather events are significantly correlated with the relocation question. The disconnect between potential flood exposure and residential opinions on risk and relocation shines a light on an emerging crisis in Hampton Roads. Older, vulnerable populations living in flood-risk areas are likely to experience increased exposure and impacts from continued storm surge flooding, and their experiences with flooding up to this point have generally not prepared them for future impacts. Policymakers can use these results to understand their role in supporting community members' relocation efforts by providing sufficient monetary support and housing options. A more informed policy can benefit the older residents in Hampton Roads, and the results from this study should be built upon to produce more policy suggestions for future flooding.

Appendix

Correlation results for the survey questions and dependent variable asking "Would you consider permanent relocation should the flooding in your community become more frequent and severe?"

Sociodemographic characteristics

Variable	*Spearman ρ*	*Prob>|ρ|*
What is your age?	0.0066	0.9562
What is your race?	0.0878	0.4632
Living alone	-0.1693	0.1552
Living with another adult (partner or spouse)	0.2313	0.0506
Living with other adults (roommates)	-0.2313	0.0506
Living with adults over the age of 65	-0.1693	0.1552
Living with children under 18 years of age	-0.074	0.5367
What is the highest level of education you have completed?	0.2223	0.0606
What is your household income?	0.0859	0.4733

Do you and your family own your home or apartment, pay rent, or have some other arrangement?	-0.0296	0.8052
For how long have you been living in the same community?	0.0397	0.7403

I feel attached to this community because there is:

by Variable	*Spearman ρ*	*Prob>|ρ|*
Plenty of open space (e.g., parks, greenways, biking and hiking trails)	0.023	0.8477
Very few abandoned/vacant properties	0.0836	0.4849
Low levels of crime	0.1236	0.301
Plenty of amenities and gathering places	0.0527	0.6599
Well-established, long-standing community	0.013	0.9135
Many historic landmarks	0.1478	0.2153
Not much changes, no new development	-0.0953	0.4258
Presence of social and recreational features (e.g., churches, playgrounds, libraries, shopping and amenities, and recreation facilities)	0.1534	0.1982
Presence of infrastructure or industrial features (e.g., factory, airport, highway, wastewater treatment facility, power plant, landfill)	0.164	0.1687
None or very few hazardous weather events or natural disasters	0.2352	0.0467

What is important to you about living in your community?

by Variable	*Spearman ρ*	*Prob>|ρ|*
My community offers social activities	0.0652	0.5864
I participate in the community activities	-0.1772	0.1364
I work in the community	-0.0836	0.4849

I have family in the community	-0.0502	0.6751
I have friends in the community	0.0145	0.9037
I have the same ethnic group in the community	0.2241	0.0584
I like the proximity to the beach and ocean	-0.008	0.9467
I have a community that would support me in times of need	0.2012	0.0902
Amenities I need are located close to where I live	-0.1601	0.1792

Flood Experience

by Variable	*Spearman ρ*	*Prob>|ρ|*
Sunny day, nuisance, or tidal flooding	-0.0584	0.6258
Storm surge during storm events (e.g., tropical storms, hurricanes, nor'easters)	0.0015	0.99
Rainfall or extreme rain events	0.1339	0.2623
How would you rate your personal risk vulnerability to flooding	0.0947	0.4289

Up to this date, which of the following did you experience due to flooding?

by Variable	*Spearman ρ*	*Prob>|ρ|*
Difficulty to commute to work	0.0016	0.9896
Canceled doctors and other appointments	0.0102	0.932
School delays and closures	-0.0704	0.557
Business delays and closures	-0.049	0.6825
Damage to personal vehicle	-0.1319	0.2693

Property damage	-0.0102	0.932
Negative impact on home value	-0.1503	0.2075
Difficulty to obtain homeowners insurance	-0.1817	0.1266
Neighbors selling homes and moving out	-0.1374	0.2496
Neighbors moving out and renting their homes	-0.1223	0.3063
Nothing at all	-0.0658	0.5827

I would consider permanent relocation if:

by Variable	*Spearman ρ*	*Prob>|ρ|*
I experience one more flood in the next year	0.0477	0.6906
I experience two or more floods in the next year	0.0756	0.5278
Neighbors, friends, and family move out	-0.0456	0.7039
Businesses are closed	0.0215	0.858
Crime becomes worse	0.1642	0.1682
School system deteriorates	0.0941	0.4319
I cannot access services and amenities due to flooding	0.1529	0.1996
Insurance cannot cover flood damage	0.2221	0.0608
I am offered with financial compensation (buyout)	0.4025	0.0005
I can move together with my neighbors	-0.0941	0.4315
I receive assistance with finding a new job elsewhere	0.023	0.8477
I am provided with free legal advice on my options	0.2079	0.0797

I cannot afford to pay taxes for a coastal property	0.2159	0.0686
I am offered with comparable housing in similar community elsewhere	0.2273	0.0548