# Evacuation Behavior of Households Facing Compound Hurricane-Pandemic Threats

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**SYMPOSIUM ARTICLE**

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**Abstract**

This study examines households' prospective evacuation behavior during a hurricane-pandemic compound threat. Data from a 2020 survey of coastal Virginia households help answer two questions: (1) What factors associated with the threat and impacts of the COVID-19 pandemic and hurricanes influence the prospective evacuation behavior of households during a compound hurricane-pandemic event? (2) What are the equity implications for emergency management policies and practices to support evacuation and sheltering during a compound hurricane-pandemic event? Households in the sample were split between those who stated they would evacuate away from the at-risk region and those who would stay. Greater household vulnerability to hurricanes and COVID-19 and having sufficient financial resources increase the likelihood of evacuation. Higher-income households were more likely to have resources to evacuate and were less likely to suffer financial consequences from a hurricane or pandemic. Racial minorities are more vulnerable to the pandemic and face greater resource challenges when evacuating.

**Evidence for practice**

- Households consider both the hurricane and COVID-19 threats as drivers for evacuating away from the at-risk area, with greater vulnerability to both hazards increasing the likelihood of a prospective evacuation.
- The household's resource base specific to the hurricane threat—having enough cash and/or credit to evacuate—positively influence prospective evacuation behavior during a compound hurricane-pandemic event.
- The household's resource base and the vulnerability of this resource base to hurricane impacts influence whether the household anticipates evacuating.
- Households that identified as racial minorities were less likely to have the financial resources needed for evacuating outside of the region and were more likely to suffer negative consequences of decreased income resulting from the pandemic and being unable to pay the rent or mortgage due to hurricane-related wage loss.
- Higher-income households were more likely to have sufficient case and credit to evacuate and were less likely to be vulnerable to the negative resource effects of the pandemic and hurricane.

At the start of the 2020 Atlantic hurricane season, the COVID-19 pandemic was taking hold, requiring adjustments to emergency management strategies for hurricanes. Hurricane evacuation and mass sheltering were at odds with virus contagion strategies, such as social distancing and self-isolation (Dargin et al., 2021; Pei et al., 2020), and concerns about virus transmission were being considered as part of hurricane preparedness and response. COVID-19 compounded the risks faced by residents and increased the complexity of government planning to protect the health and lives of the public (Pei et al., 2020; Whytlaw et al., 2021; Yusuf et al., 2020).

People and groups are differentially vulnerable to hazards given where they are situated within the natural and built environments, the economic structure, and the social and institutional fabric of a community. The health, economic, and social impacts of the COVID-19 pandemic broadened the definition of individuals and groups considered vulnerable (Whytlaw et al., 2021). Furthermore, the pandemic exacerbated socio-economic and health inequities that underpin vulnerability, negatively affecting the ability to cope with the threat of a hurricane during the pandemic.

When confronted with the threat of a hurricane, households must decide whether to evacuate or stay. Ordering the evacuation and providing shelters are the government's responsibility. Understanding household evacuation and sheltering behavior informs the government's response and is particularly relevant under a behavioral public policy framework. Knowledge of which households will leave versus stay in the area influences the capacity to evacuate residents out of the region, transportation routing and options, and the needs of public shelters.

During a compound event involving a hurricane and the COVID-19 pandemic, hurricane evacuation complicates COVID-19 virus containment and forces households to make tradeoffs between different risk reduction strategies. Fears about the virus and pandemic-related financial strain make evacuation behavior difficult to predict as they may change the propensity of households to evacuate. Fears of contracting COVID-19 within evacuation environments may change the decisions of households that would otherwise evacuate and move away from areas at physical risk. Financial strain from the pandemic could make households less likely to evacuate given the needed resources of doing so (Hill et al., 2021; Whytlaw et al., 2021).

The purpose of this article is to examine the anticipated evacuation behavior of households facing the compound threat of the COVID-19 pandemic and a hurricane. The research questions are: (1) What factors associated with the threat and impacts of the COVID-19 pandemic and a hurricane influence the prospective evacuation behavior of households during a compound hurricane-pandemic event? (2) What are the equity implications for emergency management policies and practices to support evacuation and sheltering during a compound hurricane-pandemic event?

## BEHAVIORAL PUBLIC POLICY

The COVID-19 pandemic has emphasized the need for and relevance of the behavioral public policy approach. Research knowledge "must speak not only to the daunting challenge of COVID-19 itself but also to policymakers, and indeed humankind, trying to cope with future unexpected but high impact threats… by leveraging better public policies and building administrative capacities to enable more resilient, equitable and effective public service" (Dunlop et al., 2020, p. 366). This research adopts a behavioral approach to understand how people respond to public policies (de Jonge et al., 2018; Sanders et al., 2018). More specifically, this behavioral public policy lens can be helpful in understanding household compliance with policy directions, such as evacuating during a hurricane, providing information useful for better policy design and implementation by incorporating localized or context-specific considerations (Jacobs, 2018).

Unlike the traditional approach, where policy makers reward compliance or punish non-compliance and focus on the supply side of using government resources to affect policy outcomes, the behavioral approach recognizes the demand side and the complexity of the policy targets' behaviors. "Given that the aim of most public policy is to invoke behavioral change… compliance with government intentions has always been an important part of policy scholarship" (Leong & Howlett, 2020, p. 207). The behavioral approach allows for more nuanced investigation of how people respond to government intervention by focusing on understanding the basis upon which compliance is likely to occur.

The COVID-19 pandemic illustrated the challenges of the government's capacity to make people do what they might not normally do, especially when facing a crisis. As Anderson (2022) noted, the government's use of policy tools shapes people's behaviors, while people simultaneously interpret the government's policy instructions through their own lenses and are shaped by their own perceptions of risk, experiences, and resources. In this way, "state actions and citizen attitudes combine to shape people's willingness to adapt in times of crisis" (Anderson, 2022, 1). In situations such as when faced with the threat of a hurricane during a pandemic, effective emergency response requires voluntary cooperation and compliance by the public (Anderson, 2022; Connolly et al., 2020).

A key objective of emergency response planning during a hurricane is to ensure that residents leave the at-risk area in a timely manner and get to safety (Dulebenets, 2021). Emergency shelters may be available for those with medical needs or unable to evacuate, but shelter capacity is limited. Policies are designed to protect the public during disasters, and compliance with such policies can have life-or-death consequences (Connolly et al., 2020; Dulebenets, 2021). Results of evacuation non-compliance can be catastrophic, placing at risk the safety

and lives of residents and emergency responders. This research provides insights into how government officials can design and implement evacuation-related policies that facilitate compliance with government calls for evacuation ahead of a hurricane. The research context is important given that frequent and compounding hazards are expected in the future. Furthermore, some of the factors that impact compliance may have implications for equity in terms of ability to comply and disaster outcomes. This research offers insights for ensuring that guidance or directives address such inequities.

## HURRICANE EVACUATION DURING A PANDEMIC

Under a compound hurricane-pandemic threat, households confront multiple risks from the hurricane and COVID-19 infection and face barriers that impede their ability to evacuate. The Protective Action Decision Making (PADM) model (Lindell & Perry, 2012) offers a starting point for understanding the drivers of household evacuation as a protective behavior and how these may lead to disparities and inequities in emergency responses to a hurricane-pandemic compound threat. Perceptions about the threat and protective behavior itself are part of the decision-making process. The household's assessment of the hurricane or pandemic risk and their specific vulnerabilities influence evacuation behavior, with greater hurricane vulnerability increasing the likelihood of evacuation and greater vulnerability to infection decreasing the likelihood of evacuation.

In terms of perceptions of evacuation options, Lindell and Perry (2012) recognize the roles of hazard- and resource-related attributes. Limited access to financial resources for evacuating is a resource-related attribute, and medical fragility is a hazard-related attribute that, when perceived by households as impediments to evacuation, reduces the likelihood of evacuating. The hazards themselves can pose situational impediments to evacuation by reducing a household's resource base and introducing hazard-specific challenges. Characteristics of the household, including socio-economic characteristics, are precursor factors in evacuation decision-making. For example, household income and race may contribute to disproportionate vulnerabilities and exacerbate barriers to evacuation. Working through vulnerabilities and impediments to evacuation, these characteristics may influence a household's evacuation behavior.

Consistent with the PADM model, households are differentially vulnerable to compound hurricane-pandemic hazards according to their physical location within the natural and built environment, their social networks, and their socio-economic characteristics. How their resource bases are impacted by hazards also varies with these vulnerabilities. Factors such as limited access to resources and medical fragility are barriers that make it less likely for households to evacuate.

## Physical vulnerability and proximity to hurricane risks

Approximately 94.7 million people reside in coastline communities in the U.S., with an estimated 60 million living in areas at highest risk of hurricane impacts (U.S. Census Bureau, 2021). Residing in a high-risk area subject to storm surge, flooding, and strong winds from a hurricane influences a household's perception of its physical vulnerability and determines whether a household evacuates (Baker, 1991; Huang et al., 2016).

## Proximity to COVID-19 risk

Proximity to high-risk areas for COVID-19 infection reflects vulnerability specific to the pandemic. The concept of social propinquity addresses COVID-19 vulnerability from a social network perspective (Vigo et al., 2021). People are more likely to interact with those with whom they have close social proximity, and in pandemic situations with stay-at-home orders, they are more likely to rely on these close contacts. Having someone in their social network infected with the virus increases exposure to the virus and recognition of the risk; both increase the perceived vulnerability to COVID-19.

The most immediate relationship a household may have with COVID-19 is if a household member is or has been sick or died from COVID-19. This represents immediate nearness through the spatial proximity and closeness in terms of being within the center of the household's social network. Such immediacy increases the perception of risk and vulnerability to the virus. This may decrease households' consideration of evacuating toward a greater tendency to shelter-in-place at home. Households also experience COVID-19 through connections with others outside the household, reflecting less immediate propinquity and perceived vulnerability to COVID-19 given household members' locations within a larger social network. As the propinquity and perceived risk of the virus decrease, the greater weight the household may place on hurricane risk reduction strategies compared to strategies to reduce infection. Botzen et al. (2022) found that COVID-19 concerns overshadowed flood risk perceptions and negatively impacted the intention to evacuate.

## Impediments to evacuation

Some households may not evacuate due to impediments, such as resource constraints, fear of disruption to medical care, physical mobility concerns, and limited transportation access. Resource constraints feature repeatedly in different disasters (Donahue & Tuohy, 2006), and limited access to resources is a contributor to vulnerability. Since evacuation can require significant financial resources to cover transportation, fuel, lodging, and meals (Huang

et al., 2016), households with greater financial resources are more likely to evacuate (Elliott & Pais, 2006).

Limited resources also factor into vulnerability to COVID-19. For example, lower-income households are more likely to live in housing that is overcrowded and/or in poor condition (Brennan, 2009), exposing them to greater infection risks. Resource-constrained individuals are more likely to work in in-person environments, such as food service, retail, and hospitality and have lower-paying jobs, limited savings, or no paid sick leave, thus having less flexibility to stay home when sick (Rosemberg et al., 2021).

The COVID-19 pandemic may challenge hurricane evacuation as households face economic stressors from business slowdowns and closures, such as job loss, job insecurity, and a decline in income. Simultaneously, households incur additional costs to prevent infection, further eroding their resource base and ability to evacuate during a compound hurricane-pandemic event (Whytlaw et al., 2021; Yusuf et al., 2020).

Medically fragile households have a lower propensity to evacuate. Health problems, such as physical disability or reliance on in-home medical devices are barriers hindering evacuation (Christensen et al., 2007; Willigen et al., 2002). Medical fragility becomes a greater impediment to hurricane evacuation during a pandemic given existing comorbidities that increase vulnerability to the virus. Households with medically fragile members may focus more on reducing infection risk and might be deterred from evacuating for fear of virus exposure.

## Social equity concerns

Social equity and concerns about fairness, rights, justice, and freedom from the effects of bias that underpin access, distribution, and outcomes (Guy & McCandless, 2020) are critical to disaster management, especially as it relates to being able to mitigate, prepare, respond, and recover (Emrich et al., 2020; Rivera & Knox, 2022). Social equity underpins a community's disaster resilience and reduces disproportionate impacts (Doorn et al., 2019).

Factors contributing to households' evacuation behavior in a compound hurricane-pandemic are intertwined with pre-existing health and socio-economic inequities, and these inequities may exacerbate vulnerability (Deslatte et al., 2020; Whytlaw et al., 2021). Differential capacities and responses further increase disparities and inequities in the community after disasters (Doorn et al., 2019; Gaynor & Wilson, 2020; Shaughnessy et al., 2010). Understanding how socio-economic characteristics differentially contribute to vulnerabilities or disproportionately create barriers to evacuation is crucial for developing policies and programs that ensure an equitable disaster response.

Health disparities and inequities are intertwined with COVID-19 vulnerability (Gray et al., 2020; Whytlaw et al., 2021). While COVID-19 presents risks to everyone, some groups are more vulnerable to COVID-19 impacts. Racial and ethnic minority groups had higher infection and death rates from COVID-19 (Lee & Ahmed, 2021). Existing disparities exacerbate COVID-19 outcomes for people of color as minority populations have an increased prevalence of underlying health conditions such as diabetes, heart disease, and obesity (Gaynor & Wilson, 2020; Killerby et al., 2020).

Disproportionate vulnerabilities experienced by socially marginalized groups make it challenging for households to evacuate, while continued social injustices and inequalities amplify pandemic impacts (Gaynor & Wilson, 2020). These can exacerbate the impacts of hazards, making communities more vulnerable to human suffering (CDC, 2018; Gaynor & Wilson, 2020). Public administrators and emergency management professionals specifically must emphasize social equity in framing government responses to the pandemic (Deslatte et al., 2020; Gaynor & Wilson, 2020), especially when the pandemic compounds other hazards. Within the context of emergency management, Rivera and Knox (2022) define social equity in a way that comprehensively encompasses the provision of services to every social group and efforts to reduce social vulnerability that contributes to damages from various types of hazards. However, while all groups of residents need to be provided with equal attention in disaster response, this study focuses on the specific challenges faced by under-resourced and minority groups. Attending to the specific needs of these social groups will also benefit the whole community, as strengthening the resilience of these groups will contribute to that of the overall population.

## Methodology

The research questions are centered on the prospective evacuation behaviors of households residing in the coastal Virginia region of Hampton Roads during the 2020 Atlantic hurricane season. This region, home to more than 1.8 million people, is vulnerable to coastal hazards such as tropical storms and hurricanes (major hurricane tracks impacting the region are shown in Figure 1). It has had its share of COVID-19 impacts (see Table 1) and, like the rest of the state, was under a COVID-19 stay-at-home order from March through May 2020.

Data are derived from a random, stratified survey of Hampton Roads households conducted in September and October 2020 to identify risk perceptions and potential behaviors regarding evacuation and sheltering during the COVID-19 pandemic. The survey instrument was developed with input from subject matter experts from the Virginia Department of Emergency Management and the Virginia Health Equity Working Group. The survey used a pre-screened telephone sample supplemented with a web-based survey. The sample of 2200 households was collected via telephone (31.7% landline and 54.1% mobile) and web responses (14.1%).

**FIGURE 1** Study area hurricane and storm tracks from 2000 to 2020. Hampton Roads localities included in the study are Accomack County, City of Chesapeake, City of Hampton, City of Newport News, City of Norfolk, Northampton County, City of Poquoson, City of Portsmouth, City of Suffolk, and City of Virginia Beach.

**TABLE 1** Number of COVID-19 cases per 100,000 population as of November 1, 2020 and October 17, 2022.

| City/county | November 1, 2020 | October 17, 2022 |
|---|---|---|
| Accomack County | 3672 | 25,526 |
| City of Chesapeake | 2018 | 24,354 |
| City of Hampton | 1603 | 26,058 |
| City of Newport News | 1765 | 25,201 |
| City of Norfolk | 2312 | 20,757 |
| Northampton County | 2741 | 22,921 |
| City of Poquoson | 819 | 22,386 |
| City of Portsmouth | 2923 | 26,042 |
| City of Suffolk | 2478 | 24,621 |
| City of Virginia Beach | 1782 | 23,878 |

*Source*: Data on COVID-19 cases from the New York Times, based on reports from state and local health agencies (The New York Times, 2021a, 2021b).

First, vulnerabilities to the hazards and impediments to evacuation are examined. Second, analysis focuses on factors influencing the prospective evacuation behavior of households during a compound hurricane-pandemic event. Using a logistic regression model, evacuation behavior, measured as a dichotomous variable (evacuate or stay), is regressed on the vulnerabilities to hazards and impediments to evacuation. Third, the equity implications of hurricane evacuation during the COVID-19 pandemic are identified by analyzing how socio-economic characteristics (household income and race) influence vulnerabilities to hazards and impediments to evacuations and indirectly affect prospective evacuation behavior.

## Household characteristics

The household is the unit of analysis, which is consistent with other studies (Huang et al., 2016; Mozumder & Vásquez, 2018) and appropriate since the behavioral choice about how to respond to an impending hurricane takes place within the context of the household. The household is a fundamental social and economic unit where resources are shared and leveraged for the sustainment of the household and its members. Thus, individual perceptions are formed within this unit and often are aligned in a collective manner, especially in response to an external threat (Davis, 1976; Vermeulen, 2002). Both the risk perceptions and behavioral decisions of the household may be ascertained through those of the head of the household (Bricker et al., 2011; Hasan et al., 2011; Yin et al., 2021).

Characteristics of the household are summarized in Table 2. Most households had two to four members, and 72% did not have any children in the household. Households predominantly identified as Caucasian (66%), while 24% were African American. Approximately 47% of households reported income of $65,000 or less, being below the $76,932 median household income levels for

**T A B L E 2**  Household characteristics.

| Household size | | No. of children | | Race | |
|---|---|---|---|---|---|
| 1 | 18.4% | 0 | 71.6% | Caucasian | 65.5% |
| 2 | 36.7% | 1 | 12.4% | African American | 24.0% |
| 3–4 | 32.4% | 2 | 9.1% | Hispanic | 2.3% |
| >4 | 12.5% | 3 | 3.8% | Asian | 1.3% |
| (N = 2110) | | >3 | 3.0% | Mixed | 4.4% |
| | | (N = 2115) | | Other | 2.5% |
| | | | | (N = 1986) | |
| **Household income** | | **Multigenerational household** | | **Prospective evacuation behavior** | |
| <$25,000 | 12.5% | Yes | 9.4% | Yes | 48.6% |
| $25,000–$45,000 | 16.7% | No | 90.6% | No | 51.4% |
| $45,001–$65,000 | 18.0% | (N = 2166) | | (N = 2155) | |
| $65,001–$85,000 | 15.7% | | | | |
| $85,001–$105,000 | 12.1% | | | | |
| $105,001–$125,000 | 8.6% | | | | |
| >$125,000 | 16.3% | | | | |
| (N = 1621) | | | | | |

the region (GHR Connects, 2022). The 29% of households in the income categories of $45,000 or less can be considered low-income households, defined as those below 50% of the median household income.

## RESULTS

### Prospective evacuation behavior

Analysis of prospective evacuation behavior focuses on whether the household would choose to evacuate outside the region or stay and shelter in the region. Households were asked about their evacuation behavior during the 2020 hurricane season and the COVID-19 pandemic. They were asked: Currently, in this hurricane season, if a significant hurricane were to head for Hampton Roads, then would your household likely evacuate out of the Hampton Roads region? Those responding "Yes" to this question were categorized as prospectively evacuating away from the at-risk area during a hurricane-pandemic threat. Those responding "No" were categorized as likely staying and sheltering in the region. Across the 2155 survey respondents answering the question, 49% indicated they anticipate evacuating outside the region, and 51% plan to stay.

### Vulnerability to hurricane and COVID-19 pandemic risks

Physical vulnerability is measured using four indicators: (1) evacuation zone, (2) experience with residential street flooding, (3) having suffered injury from a weather hazard,

and (4) having suffered property loss from a weather hazard (see Table 3). Virginia utilizes a four-tiered evacuation zone system. Evacuation Zone A reflects the most vulnerable areas and covers low-lying, near-coastal areas proximate to storm surge and flooding. Households residing in Zone A will be required to evacuate (i.e., mandatory evacuation) when a hurricane is imminent. Physical vulnerability also manifests in whether the household has experienced injuries or property loss from a previous storm event and the frequency of street flooding in areas surrounding the household's residence, reflecting these households' residence in areas prone to flooding and likely to be impacted by hurricane storm surge. From these four indicators, a physical vulnerability factor score was created to measure the household's specific physical vulnerability to hurricanes.[1]

A household's specific vulnerability to COVID-19 is measured using COVID-19 propinquity, which reflects closeness to COVID-19 in terms of the social network. Almost 39% of households were categorized as having low COVID-19 propinquity, defined as those whose members do not know a person that has been infected, ill, and/or died from COVID-19. Medium COVID-19 propinquity households (31%) have members who know a person who has been ill from COVID-19, while members of high propinquity households (25%) know a person who has died from COVID-19. Households characterized as having immediate COVID-19 propinquity (6%) have members that have been infected, ill, and/or died from COVID-19.

In addition to specific vulnerabilities to the hurricane and to the pandemic, households are also vulnerable due to their combined proximity to both risks. The analysis in Table 3 shows that households are jointly affected by their proximity to hurricane and COVID-19 impacts. The

**TABLE 3** Vulnerabilities and impediments to evacuation during a compound hurricane-pandemic event.

PHYSICAL VULNERABILITY

*Evacuation zone*
Identified as Zone A, Zone B, Zone C, Zone D, or no zone, according to the state's categorization, based on physical address.
Zone A: 19.5%
Zone B: 20.2%
Zone C: 23.3%
Zone D: 19.0%
No zone: 18.0%
($N = 2133$)

*Frequency of street flooding*
How often do either the street in front of your home or streets very near your home flood?
More than once a month: 4.3%
Once a month: 6.6%
Couple time a year: 18.5%
Once a year: 6.1%
Once every couple of years: 8.6%
($N = 2091$)

*Suffered property loss from a weather hazard*
In any past severe weather events, have you or a family member suffered any property loss?
Yes: 28.9%
No: 71.1%
($N = 2166$)

*Suffered injury from a weather hazard*
In any past severe weather events, have you or a family member suffered any injuries?
Yes: 3.6%
No: 96.4%
($N = 2166$)

*Physical vulnerability factor score*
Mean: $1.84 \times 10^{-11}$
Std Dev: 0.516
Min: $-0.611$
Max: 2.529
($N = 2030$)

*COVID-19 exposure*

*COVID-19 propinquity*
• Do you or somebody in your household know a person who has died from COVID?
• Do you or somebody in your household know a person who has been sick with COVID but has not died?
• Has any member of your household been infected with COVID?
Low propinquity: 38.5%
Medium propinquity: 31.2%
High propinquity: 24.6%
Immediate propinquity: 5.7%
($N = 2170$)

*Medical fragility*

*Medically-fragile household*
• Limited in activities of daily living: How many adults living in your home are dependent upon others to help with normal daily activities such as bathing, getting dresses, feeding, or following medication schedules?
• Hearing disability: How many adults in your household have a hearing disability?
• Sight disability: How many adults in your household have a seeing disability that interferes with normal daily activities?

(Continues)

**TABLE 3** (Continued)

• Cognitive disability: How many adults in your household have a limiting mental or cognitive disability such as dementia or Alzheimer's?
• Severely handicapped child: Are there any severely disabled or handicapped children within your household?

*Medical fragility index*
Mean: 0.456
Std Dev: 0.865
Min: 0
Max: 5
($N = 2080$)

*Access to resources*

*Enough cash or credit to evacuate*
In this hurricane season, if your household had to evacuate out of the region for 5 days, does your household have enough cash or credit cards to support everyone in the household outside the region for 5 days including the cost of gas, food, and lodging?
Yes: 82.4%
No: 17.7%
($N = 2045$)

mean physical vulnerability factor score was highest for households with immediate COVID-19 propinquity, indicating that households that are vulnerable to the physical threats of hurricanes are also vulnerable to COVID-19.

## Impediments to evacuation

Access to resources needed for evacuation is measured using whether households had sufficient cash or credit cards to cover the costs (gas, food, and lodging) of evacuating household members away from the at-risk region for 5 days. Most households (82%) reported having enough cash or credit cards to support an evacuation outside the region (see Table 3).

Medically fragile households have members with conditions or impairments that limit what would otherwise be routine activities. One measure of medical fragility considers the ability to perform activities of daily living that an individual must perform to live independently. Four additional indicators reflect a household's medical fragility in terms of having a hearing disability, a sight disability, a cognitive disability, or a severely handicapped child. From these five indicators, a household medical fragility score was created as an additive index score, ranging from zero to five. Most households (71%) were not medically fragile, 19% met one of the medical fragility criteria, and 10% of households had three or more indicators of medical fragility.

## Hurricane and pandemic impacts on the Resource Base

Hurricane and pandemic impacts can pose challenges to a household's resource base. For 31% of households, the loss of a week's pay due to a storm would cause difficulty

**TABLE 4** Hurricane physical vulnerability, COVID-19 propinquity, and impact on resources.

**Physical vulnerability and COVID-19 propinquity**

| | COVID-19 propinquity | | | |
| --- | --- | --- | --- | --- |
| | Low | Medium | High | Immediate |
| Physical vulnerability factor score (mean) | −0.096 | 0.007 | 0.077 | 0.240 |
| | $F = 21.75, p < .001$ | | | |

*Access to resources: Lost wages due to storm would cause difficulty paying rent or mortgage*
If your household were to lose a week's pay due to a storm, would that cause difficulty for you in making the next month's rent or mortgage payment?
Yes: 30.6%
No: 69.4%

| | Lost wages | |
| --- | --- | --- |
| | Yes | No |
| Physical vulnerability factor score (mean) | 0.088 | −0.041 |
| | $\chi^2 = 59.12, p < .001$ | |

*Access to resources: Pandemic impact on income*
Has your overall household income decreased, increased, or stayed about the same due to COVID?
Decreased: 21.5%
Stayed about the same or increased: 78.5%

| | Pandemic impact on income | |
| --- | --- | --- |
| COVID-19 propinquity | Decreased | Stayed the same or increased |
| Low | 16.4% | 83.6% |
| Medium | 21.8% | 78.2% |
| High | 26.0% | 74.0% |
| Immediate | 34.5% | 65.5% |
| | $\chi^2 = 30.030, p < .001$ | |

in paying the next month's rent or mortgage payment. For these households that often live paycheck to paycheck, hurricane-related disruptions to wages can affect the ability to pay important household expenses. Table 4 shows the relationship between hurricane-related physical vulnerability and resource vulnerability. Households that indicated that storm-related loss of pay would cause difficulty paying the rent or mortgage had, on average, higher physical vulnerability scores.

Pandemic-related impacts on the resource base are shown in Table 4. Overall, 22% of households indicated decreased income due to the pandemic, with the percentage of households that experienced pandemic-related income reductions increasing with greater COVID-19 propinquity. For example, 35% of households with immediate COVID-19 propinquity indicated negative impacts of the pandemic on income, while 16% of low propinquity households saw such an impact.

## LOGIT REGRESSION RESULTS

A logit regression model was estimated to identify factors that contribute to households' prospective evacuation behavior. Evacuation behavior was regressed on physical vulnerability to the hurricane threat, COVID-19 propinquity,

lack of resources to evacuate, medical fragility that challenges evacuation, and hurricane- or pandemic-related negative impacts to the resource base. Regression results are summarized in Table 5.

Physical vulnerability to the hurricane threat and COVID-19 propinquity were statistically significant in explaining prospective evacuation behavior. Households that were more physically vulnerable to hurricane impacts were more likely to evacuate. Contrary to the expectation that greater vulnerability to and concern for infection would reduce the likelihood of evacuating, higher COVID-19 propinquity households were more likely to evacuate outside of the region.

Medical fragility was also not an impediment that reduced the likelihood of prospective during a compound hurricane-pandemic event. From a resource perspective, having sufficient cash or credit to evacuate was statistically significant as a factor that increased evacuation. Households that indicated that wage losses from a storm would cause difficulty in paying the rent or mortgage were expected to have fewer resources and were therefore less likely to evacuate. Results in Table 5 show the opposite. The positive and statistically significant coefficient suggests that households vulnerable to storm-induced disruptions to their paychecks are more likely to evacuate. Pandemic impacts on household income, however, were not statistically significant as a factor in a household's decision to evacuate.

## Equity implications

The logit model examined how hurricane and pandemic vulnerabilities and access to resources contribute to households' prospective evacuation behavior. However, these factors may be disproportionately experienced by households with different socio-economic characteristics. An analysis of evacuation behavior must consider the underlying disparities and inequities that amplify vulnerability or reinforce barriers to evacuation. Figure 2 traces the direct and indirect effects of factors that introduce equity concerns into hurricane evacuation during a pandemic. Factors such as household income and race, which are associated with disparities and inequities, telegraph through household resources and medical fragility to shape the households' evacuation behavior.

Full results of the regression models for the relationships shown in Figure 2 are provided in Appendix Table A1. Neither household income nor race were related to specific hurricane vulnerability. However, higher-income households were more likely to have greater COVID-19 propinquity, which is contradictory to lower income households being employed in frontline functions with greater virus exposure and having fewer remote work opportunities. Households identifying as racial minorities were more likely to have greater COVID-19 propinquity, pointing to disproportionate racial impacts on COVID-19 vulnerability. However, since greater COVID-19 propinquity increases the likelihood of prospective evacuation away from the hurricane risk, these disproportionate impacts may be reduced along the path toward evacuation behavior. A negative relationship between household income and medical

**TABLE 5** Results of the logit model for prospective evacuation behavior.

| Prospective evacuation behavior | Expected relationship | Coeff. | Std. err | p-value |
|---|---|---|---|---|
| Physical vulnerability score | + | 0.290 | 0.102 | .005 |
| COVID-19 propinquity | − | 0.144 | 0.055 | .008 |
| Medical fragility score | − | 0.046 | 0.058 | .433 |
| Enough cash or credit to evacuate | + | 0.243 | 0.145 | .094 |
| Lost wages due to storm | − | 0.206 | 0.123 | .093 |
| Income decreased due to pandemic | − | 0.042 | 0.125 | .740 |
| Constant | | −0.453 | 0.161 | .005 |

$N = 1757$

Likelihood ratio $\chi^2(6) = 26.11$, p-value $= .0002$

Cragg & Uhler's $R^2 = .015$

McKelvey & Zavoina's $R^2 = .018$
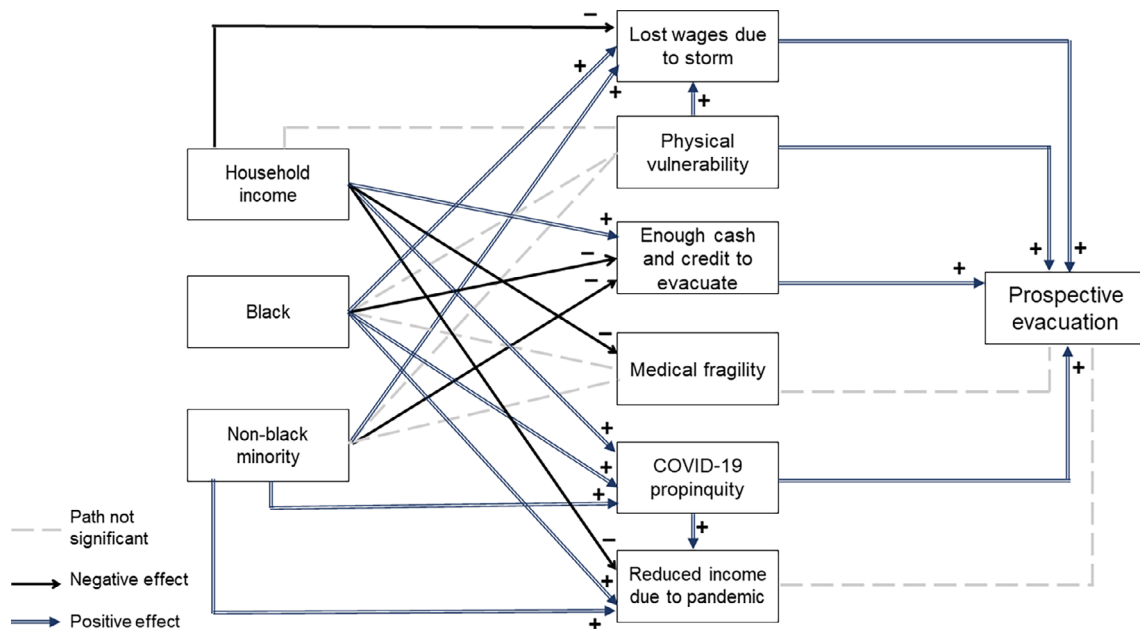
McFadden's $R^2 = .011$



**FIGURE 2** Direct and indirect effects of vulnerabilities, impediments to evacuation, and socio-economic factors.

fragility indicates more low- income households are medically fragile. There was no relationship between race and a household's medical fragility.

Socio-economic characteristics factor heavily into households' resource bases. Household income positively contributes to having enough resources to evacuate, and a higher income provides protection from the negative consequences of a hurricane or pandemic. Higher-income households are less likely to have their ability to pay housing costs negatively impacted by hurricane-related wage loss and to experience pandemic-related income reductions. Households identifying as racial minorities were less likely to have the financial resources needed for evacuation and more likely to experience lower income due to the pandemic and a decreased ability to pay rent or mortgage because of wage loss from a storm.

## DISCUSSION OF FINDINGS

Responding to a hurricane during a pandemic requires households to consider different factors when deciding on prospective evacuation behavior. Households in the sample were evenly split between those who anticipated evacuating away from the at-risk region (49%), and staying in the region (51%). Household evacuation rates vary widely depending on a range of local factors, and there is no consensus on what an appropriate evacuation rate is across all hurricane or storm scenarios. However, the fact that almost half of the households indicated they would not evacuate and instead risk their and the responders' lives by remaining in the area is concerning. This reinforces the need to answer the research question related to which hurricane- and pandemic-related factors influence households' evacuation behaviors. This prospective evacuation rate also has implications for local sheltering needs, as people may need to leave their flooded or damaged homes but are unable to exit the region in the middle of a hurricane.

Findings show that during the compound hurricane-pandemic event, households respond to both risks. Households residing in areas vulnerable to storm surge and flooding are more likely to evacuate. However, households with greater COVID-19 exposure are also more likely to evacuate out of the region. One interpretation is that these households are less concerned about exposure to COVID-19 while evacuating, since they may be able to manage risk through strategies such as wearing masks and using extra cleaning procedures, than they are about virus exposure in a public shelter if they do not leave the at-risk region and may have to seek safety at a mass shelter. Results also show overlap between hurricane and pandemic vulnerabilities. The vulnerabilities due to proximity to physical and infection risks both lead to a greater likelihood of evacuating.

Medically fragile households were expected to be less likely to evacuate. However, the analysis shows that

medical fragility was not a factor in determining a household's prospective evacuation behavior. It is possible that the household's medical fragility plays into prospective evacuation behavior in two opposing ways that cancel out its effects. The first is that, as suggested by the literature, having household members with disabilities or medical impairments may make it challenging to evacuate (Whytlaw et al., 2021; Yusuf et al., 2020). Medically fragile households may instead seek safety in public shelters that are equipped to meet their needs. However, in the case of a newly emerging pandemic, these households may be more concerned about virus contagion within a mass shelter, prompting them to evacuate away from the region.

Findings regarding resource limitations as a barrier to evacuation are consistent with expectations. Households without sufficient financial resources to support evacuation were less likely to indicate they anticipate evacuating during a compound hurricane-pandemic event. Additional analysis focused on how the household's resource base was vulnerable to the impacts of a hurricane or pandemic. Only hurricane-related resource impact was a factor in households' prospective evacuation behavior during a compound hurricane-pandemic event. Households whose resource bases are vulnerable to storm-caused wage losses, such as those who work in the hospitality or tourism sectors or whose employment is likely to be disrupted by a storm event, were more likely to evacuate. While this vulnerability might include minority households, it more broadly captures those households that are more immediately impacted by the economic disruptions of a hurricane. Furthermore, since these resource-vulnerable households are also physically vulnerable to a hurricane, physical vulnerability impacts prospective evacuation indirectly through this resource vulnerability.

The analysis also looked at how a household's general resource base (income) influences vulnerability and creates barriers to evacuation. This examination, coupled with that of race, is critical for identifying equity implications for emergency management policies and practices to support evacuation and sheltering during a compound hurricane-pandemic event. Results point to household income and race factoring heavily in terms of resource-related impediments to evacuation. Households with higher incomes were more likely to have the financial resources needed for evacuation and were less likely to suffer negative financial consequences from a hurricane or pandemic. Households identifying as racial minorities were less likely to have sufficient cash and credit available to evacuate outside of the region and are more likely overall to be negatively impacted by events such as decreased income due to the pandemic or reduced ability to pay the rent or mortgage due to lost wages from a hurricane event. Combined, these findings point to social equity concerns regarding household evacuation during a compound event since lower-income households and racial minorities experience disproportionate impacts to their resource base, creating disparities in their ability to

evacuate and subsequently contributing to decisions about prospective evacuation.

Households are differentially vulnerable to the pandemic given their race, with minority households having greater exposure and vulnerability to COVID-19. These households also disproportionately face greater impediments to evacuation in terms of limited access to resources and increased vulnerability of their financial resources to hurricane and pandemic impacts. However, while income and race are used in this study to illustrate how socio-economic factors contribute to inequities, other factors such as education and immigrant status may also introduce or exacerbate disparities. By recognizing that households are disproportionately vulnerable and impacted given their race, income, and other socio-economic characteristics, policy makers and emergency managers can develop and implement policies, programs, and practices that directly support these households, such as through targeted allocation of resources or programs that assist these households with evacuation planning specific to their needs.

## CONCLUSION

Evacuation during a compound hurricane-pandemic event removes people from the physical impacts of storm surge, flooding, and strong winds but may increase the risk of virus exposure and infection as people congregate. Households undertake different evacuation behaviors during a compound threat than if they were to only consider the threat of the hurricane, necessitating adjustments to emergency management response strategies. These adjustments must be based on an understanding of how households are vulnerable to the risks and impacts of hurricanes and pandemic threats, how barriers impede evacuation, and how vulnerabilities and barriers to evacuation are differentially experienced across a community. Policies, processes, and practices must recognize the need for and incorporate equity in emergency response. Recognizing that compound threats require thinking about vulnerability more expansively and equity more explicitly is critical since compounding hazards will be more frequent and severe in the future.

Research is emerging that looks at hurricane response during the COVID-19 pandemic (Botzen et al., 2022; Collins et al., 2021; Collins, Polen, Dunn, Jernigan, et al., 2022; Collins, Polen, Dunn, Maas, et al., 2022; Hill et al., 2021), but more is needed to understand households' evacuation behavior to develop responsive and equitable policies, processes, and practices. This study focused on households' prospective evacuation behavior when facing threats of a hurricane during a pandemic and identified equity implications for disaster management. Survey data revealed that similar percentages of households would evacuate away from the at-risk area as they would stay and shelter in the region. Evacuation behavior varied according to factors specific to the hurricane and COVID-19 threats. More importantly, there was overlap between hurricane and COVID-19 vulnerabilities, and both were positive factors contributing to decisions to evacuate. In theory, risk reduction strategies for hurricane and pandemic threats are at odds, but given the trade-offs between the two, physically vulnerable households were more likely to evacuate outside of the region to remove themselves from the possibility of virus exposure in unmanageable situations such as in public shelters. Households have more control over infection risk mitigation while evacuating than they do mitigating hurricane impacts if they stayed in the at-risk area.

Resource limitations were important barriers preventing households from evacuating. However, the analysis also shows how vulnerabilities and impediments to evacuation that are part of the evacuation considerations only explain one piece of the puzzle in terms of understanding the equity issues of evacuation and sheltering during a compound hurricane-pandemic threat. An analysis of disparities in vulnerability and resource base points to inequities according to socio-economic characteristics. Under-resourced and minority households are disproportionately vulnerable to and impacted by hurricane and pandemic threats, which translates into disparities in terms of barriers to evacuation.

This research has implications for the joint consideration of emergency management and equity in the post-pandemic world of increased compound hazards. Understanding how evacuation and sheltering decisions vary across populations with different socio-economic characteristics and vulnerabilities is crucial for developing policies that ensure equity in disaster response. The findings offer implications for policies, processes, and practices that explicitly incorporate vulnerability and equity into emergency management planning and operations, such as by expanding and targeting protections for vulnerable populations by addressing barriers to evacuation.

The COVID-19 pandemic exacerbated disparities and inequities, affecting their ability to cope with the threat of a hurricane during the pandemic. Identifying the most affected segments of the population allows for targeted efforts to support and inform household preparedness toward evacuating away from hurricane risk while reducing the disproportionate impacts of such an evacuation. Disparities and inequities that promulgate challenges for evacuation need to be explicitly considered. The COVID-19 pandemic has its own inequities and disparities that must be addressed for an effective disaster response during a compound event. Policies, processes, and practices must recognize and consider the midstream and upstream social determinants of health that contribute to COVID-19 disparities while simultaneously influencing the capacity of households to respond to hazards.

Cegan et al. (2022) emphasize how pre-existing disruptions such as socio-economic disparities, inadequate housing, and systemic racism combined with the acute disruptions of a hurricane and pandemic lead to compounding impacts.

The nexus between (1) hurricane and pandemic hazards and (2) emergency management and public health responses illustrates how efforts to protect the public during a compound hurricane threat require emergency management and public health to work together. Furthermore, an equitable response requires involvement from other functions, including transportation, social services, and public information, and with involvement of the private sector and nongovernmental organizations (Gray et al., 2020; Whytlaw et al., 2021; Yusuf et al., 2020). Since hurricanes and the pandemic can negatively impact resources, vulnerable households may require more resources to evacuate away from the hurricane risk or to shelter in the area. Supporting these households equitably will require participation by a broader list of government and nongovernmental organizations.

In terms of implications for emergency management responses to compound hazards more broadly, the findings point to the need to consider risks, vulnerabilities, and impacts more expansively in terms of specific risks (such as those of a hurricane or pandemic individually) and compounded risks (such as those from a combined hurricane and pandemic). Future research on compound threats should begin with conceptual development that identifies the different dimensions of vulnerability, defines the respective vulnerability constructs and how they may overlap or interact, and develops frameworks or models that connect vulnerability to antecedents and subsequent behaviors related to the compound hazards. Empirical research can test these models and frameworks with the goal of validation, refinement, and results that inform application to a wide range of compounding hazards.

There are several limitations to this research. First is the prospective nature of the questions in the stated preferences survey. The survey was conducted during the hurricane season, when there was heightened awareness of hurricane risk, though the questions posed did not reference a named storm. The use of intention to evacuate is consistent with studies of prospective or hypothetical behavior, and research findings are consistent between studies of intended and actual behavior (Huang et al., 2016; Kang et al., 2007; Whitehead et al., 2000).

Future research can analyze actual evacuation behavior and compare prospective and actual behavior for compound hazards to provide useful insights into how intentions translate into behavior. Additional behavioral research using a social psychological lens could be useful for understanding intentions and behaviors. Furthermore, understanding the connection between prospective and actual behavior can help determine how researchers and practitioners can use understanding of prospective behaviors to inform the design of policies, processes, and practices.

Another limitation is that the analysis only looked at evacuation away from the at-risk region and does not consider within-region evacuation, where households evacuate from locations at higher risk of storm surge to those at lower risk. In terms of geographic focus, the survey was confined to the coastal Virginia region and thus has limited generalizability. Other vulnerable populations across the Eastern seaboard, on the Gulf Coast, and in Puerto Rico have experienced hurricanes more frequently but were not included. However, there is recent research by Collins et al. (2021); Collins, Polen, Dunn, Jernigan, et al. (2022); Collins, Polen, Dunn, Maas, et al. (2022) and others (Zhao et al., 2022) on evacuation behavior in several of these states and regions. The survey methodology and analysis used in this study of coastal Virginia could be applied to other regions and in the later stages of a pandemic (e.g., the post-vaccine period) to expand the body of knowledge about evacuation behavior in different places and times. Despite these limitations, this study provides an understanding of evacuation behavior during the early pandemic stage for larger swaths of the population along the Eastern seaboard that are not as vulnerable to hurricanes.

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## ENDNOTE

[1] Factor analysis using principal factoring was utilized to create and extract one factor score. Correlation analysis and results of the Bartlett Test of Sphericity (p < 0.05) indicate commonalities among variables and the Kaiser-Meyer Olkin test (>0.5) support the factor analysis.

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## APPENDIX A

**TABLE A1** Regression models for direct and indirect effects.

| | Coeff (std. error) | p-value |
|---|---|---|
| *Linear regression model: Physical vulnerability* | | |
| Household income | 0.006 (0.007) | .428 |
| Black | −0.020 (0.034) | .547 |
| Non-black minority | −0.036 (0.046) | .426 |
| Constant | 0.006 (0.034) | .864 |
| $N = 1469$ | | |
| $F(3,1465) = 0.71, p = .548$ | | |
| $R^2 = .001$ | | |
| *Multinomial logit regression model: COVID-19 propinquity (Low is the base outcome)* | | |
| *COVID-19 propinquity: Medium* | | |
| Household income | 0.125 (0.031) | <.001 |
| Black | 0.156 (0.164) | .343 |
| Non-black minority | 0.037 (0.200) | .854 |
| Constant | −0.644 (0.147) | <.001 |
| *COVID-19 propinquity: High* | | |
| Household income | 0.135 (0.035) | <.001 |
| Black | 1.322 (0.159) | <.001 |
| Non-black minority | 0.093 (0.200) | .695 |
| Constant | −1.305 (0.170) | <.001 |
| *COVID-19 propinquity: Immediate* | | |
| Household income | 0.100 (0.057) | .080 |
| Black | 0.351 (0.290) | .226 |
| Non-black minority | 0.698 (0.303) | .021 |
| Constant | −2.332 (0.272) | <.001 |
| $N = 1549$ | | |
| Likelihood ratio $\chi^2(9) = 107.26, p < .001$ | | |
| Cragg & Uhler's $R^2 = .073$ | | |
| *Linear regression model: Medical fragility* | | |
| Household income | −0.067 (0.012) | <.001 |
| Black | 0.078 (0.055) | .159 |
| Non-black minority | −0.003 (0.076) | .972 |

(Continues)

**TABLE A1** (Continued)

| | Coeff (std. error) | p-value |
|---|---|---|
| Constant | 0.730 (0.055) | <.001 |
| $N = 1504$ | | |
| $F(3,1500) = 12.86, p < .001$ | | |
| $R^2 = .025$ | | |
| *Logit regression model: Enough cash or credit to evacuate* | | |
| Household income | 0.499 (0.045) | <.001 |
| Black | −0.682 (0.158) | <.001 |
| Non-black minority | −0.471 (0.236) | .046 |
| Constant | 0.057 (0.164) | .726 |
| $N = 1492$ | | |
| Likelihood ratio $\chi^2(3) = 189.87, p < .001$ | | |
| Cragg & Uhler's $R^2 = .194$ | | |
| McFadden $R^2 = .133$ | | |
| *Logit regression model: Lost wages due to storm* | | |
| Physical vulnerability factor score | 0.615 (0.115) | <.001 |
| Household income | −0.346 (0.034) | <.001 |
| Black | 0.768 (0.141) | <.001 |
| Non-black minority | 0.509 (0.196) | .009 |
| Constant | 0.198 (0.145) | .172 |
| $N = 1411$ | | |
| Likelihood ratio $\chi^2(4) = 185.45, p < .001$ | | |
| Cragg & Uhler's $R^2 = .173$ | | |
| McFadden $R^2 = .106$ | | |
| *Logit regression model: Income decreased due to pandemic* | | |
| COVID-19 propinquity | 0.297 (0.067) | <.001 |
| Household income | −1.888 (0.034) | <.001 |
| Black | 0.337 (0.145) | .021 |
| Non-black minority | 0.339 (0.202) | .093 |
| Constant | −0.974 (0.157) | <.001 |
| $N = 1520$ | | |
| Likelihood ratio $\chi^2(4) = 63.35, p < .001$ | | |
| Cragg & Uhler's $R^2 = .062$ | | |
| McFadden $R^2 = .039$ | | |

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