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Social vulnerability, disaster assistance, and recovery: A population-based study of Hurricane Harvey in Greater Houston, Texas

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ABSTRACT

Research has shown that post-disaster assistance may be inequitably distributed and that socially vulnerable residents may experience constraints in recovering from disasters. We examined social inequities in receipt of assistance and near-term recovery for a population-based sample of 312 Greater Houston households surveyed following Hurricane Harvey. We used generalized linear models to examine relationships between social vulnerability indicators and the receipt of assistance from all sources, and separately from government or non-government organization (NGO) sources; and we assessed how social vulnerability indicators and the receipt of assistance influenced recovery. We found that householders identifying as US-born Hispanic (vs. non-Hispanic White) (OR = 4.50; 95% CI = 1.69,12.01), householders exhibiting more post-traumatic stress (PTS) (OR = 1.02; 95% CI = 1.00,1.04), and households with more property damage (OR = 2.23; 95% CI = 1.67,2.98) had greater odds of receiving assistance from any source. Having dependent children (OR = 2.38; 95% CI = 1.24,4.57), lower income (OR = 0.87; 95% CI = 0.77,0.996), and more property damage (OR = 2.23; 95% CI = 1.66,2.99) increased households' odds of receiving government assistance. More PTS (OR = 1.03; 95% CI = 1.01,1.05) and property damage (OR = 1.77; 95% CI = 1.29,2.42) increased—while having disabled members decreased (OR = 0.37; 95% CI = 0.15,0.93)—households' odds of receiving NGO assistance. Receiving assistance did not predict greater household recovery ($b = -0.05$; 95% CI = $-0.72,0.62$), but higher income ($b = 0.22$; 95% CI = $0.09,0.36$), absence of disability ($b = -1.01$; 95% CI: $1.98,-0.03$), less PTS ($b = -0.03$; 95% CI = $-0.06,-0.01$), and less property damage ($b = -1.13$; 95% CI = $-1.45,-0.82$) did. Findings suggest that post-disaster assistance organizations should better address the needs of disabled survivors, and that risk reduction efforts should emphasize pre-event hazard mitigation and disaster preparedness to facilitate post-event recovery.

1. Introduction

Hurricane Harvey was a devastating disaster that occurred on the Texas (USA) coast. Harvey made landfall as a Category 4 hurricane on August 26, 2017 and was characterized by historic levels of rainfall and unprecedented flooding, resulting in catastrophic damage [1]. Sixty-eight deaths were directly attributable to the hurricane, as well as an estimated \$125 billion dollars in damage, making it the deadliest Texas hurricane since 1919 and the second costliest US hurricane after Hurricane Katrina [1]. While Harvey caused record damage to the Houston-The Woodlands-Sugar Land, Texas Metropolitan Statistical Area (hereafter referred to as Greater Houston), recent research has illuminated disparities in terms of which social groups were most

affected by the subsequent flooding. Flooding from Harvey was disproportionately extensive based on Black, Hispanic, disabled, and economically disadvantaged statuses at neighborhood and household levels [2–4].

Socially vulnerable populations like those disproportionately exposed to Harvey-induced flooding are at greater risk of disparate impacts from disasters in a multitude of ways. Social vulnerability refers to the social characteristics of a person or group and their situation that influence their capacity to prepare for, respond to, and recover from the impacts of disasters [5]. Social vulnerability often mirrors social disadvantage, whereby communities comprised of racial/ethnic minorities and persons of low socioeconomic status (SES) in the United States (US) experience disproportionate disaster impacts [6–8]. A review

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article concluded that flooding disproportionately inhibits recovery among low socioeconomic status (SES) groups, in part because they tend to have limited networks through which to access recovery assistance [9]. For example, low-income (vs. high-income) status in Galveston, Texas was associated with slower recovery after Hurricane Ike in 2008 [10]. Nationwide, homeowner-occupants were more likely to benefit from disasters financially compared to renter-occupants, indicating that SES, as reflected in home ownership, plays a role in recovery [11].

Racial status has also been associated with slower recovery. In the half-decade following Hurricane Andrew in Miami, home rebuilding and repairs happened more slowly in predominately Black neighborhoods than in majority White neighborhoods [12]. Among those who had sought assistance from the American Red Cross (ARC) after Katrina, Black persons from New Orleans were 2.1 times more likely to be in a worse job situation than White persons from outside the New Orleans city limits, one year after Katrina [13]. Howell and Elliott [11] found that the post-disaster recovery process across the US was unequal based on race/ethnicity, such that Black residents were more likely to lose wealth as damage from hazards increased in their counties of residence, while White residents were more likely to gain wealth.

Social vulnerability analyses should be tailored to characteristics that are contextually-relevant to particular places [5]. For Greater Houston, this includes more nuanced examination of the Hispanic population—which constitutes the area's largest racial/ethnic minority group—based on nativity (i.e., US- vs. foreign-birth) and citizenship status, since those distinctions have been associated with social inequalities in flood hazard vulnerability [14–18].

In addition to low SES, race/ethnicity, nativity, and citizenship, other social vulnerability factors are relevant to recovery. We focus on the presence of children in the household, employment status, and disability status. Children are particularly vulnerable in the context of disaster. They are psychologically vulnerable and may experience post-traumatic stress or related symptoms. They are physically vulnerable to death, injury, illness, and abuse. Children are also dependent on adults across all phases of the disaster cycle [19]. Households with children also have different needs and exhibit distinct behavior post-disaster [19, 20]. Being unemployed when a disaster strikes means that one is ineligible for Disaster Unemployment Assistance through the Federal Emergency Management Agency (FEMA), thus placing previously unemployed persons at a disadvantage during disaster recovery [21]. Persons with disabilities are also vulnerable after disasters. The lack of disability-inclusive disaster information, planning and education has often resulted in the isolation and entrapment of persons with disabilities in their homes and away from sources of assistance in disasters [22]. International relief organizations themselves have recognized that people with disabilities are “ignored or excluded at all levels of disaster preparedness, mitigation and intervention”, emphasizing the particular vulnerability of this population [23].

A crucial means for households to reduce their vulnerability following disasters is by accessing assistance resources. Households able to access forms of assistance that address their needs have better prospects for quicker and more complete recovery, while those unable to access such resources tend to have worse recovery prospects [5]. Post-disaster recovery assistance takes the forms of shorter- and longer-term solutions. FEMA's National Disaster Recovery Framework [24] identifies goals for short-term and intermediate recovery—which together we refer to in this study as a “near-term recovery”—as addressing mass care and emergency sheltering, public health and emergency medical care, debris cleanup, and emotional and psychological trauma. Long-term recovery includes providing permanent housing solutions, rebuilding infrastructure, spurring economic revitalization, and reestablishing disrupted healthcare facilities. In this study, we focus on near-term recovery assistance in the forms of debris removal; construction materials and tool provision; property repairs; distribution of clothing, food, and water; help with moving or storage; grants to cover living expenses; medical aid; loans and donations;

income tax deductions; and/or counseling.

Recovery assistance can come from various sources, such as government agencies, nongovernment organizations (NGO), private businesses, and/or social networks. Governmental assistance comes from federal, state, tribal or local levels, usually in the form of financial or technical support for local disaster recovery groups [25]. NGO assistance comes from organizations such as the ARC, civic groups, as well as religious groups, where church members provide housing, spiritual and emotional healing, flexible local and quick response actions, staffing at shelters, and other forms of assistance [26]. The assistance provided by NGOs often targets diverse and vulnerable populations at the local level; government assistance providers may also rely on communication with local NGOs to gain insight on community impacts and needs to improve their distribution of assistance [25]. Businesses in the private sector more often collaborate with one another to create task groups and forward business recovery plans to local governments, as functioning business communities are critical to providing jobs and stable tax bases and facilitating quicker recovery for affected areas [25]. A household's support system, i.e., their social networks, can also assist in recovery, with friends and family aiding in debris cleanup, housing, financing, and emotional support [27–29]. Disaster survivors with well-developed and -resourced social networks may receive targeted assistance that meets their specific household needs.

Research indicates that recovery assistance from each of those sources—government agencies, NGOs, social networks, and private businesses—can be inequitably distributed. In terms of government-sourced assistance, issues include uneven allocation and burdensome delays in providing post-disaster aid to survivors [30]. The delay of federal assistance to New Orleans after Hurricane Katrina is illustrative. When financial assistance did arrive, it was over-allocated to less severely affected, higher-class White citizens and under-allocated to lower SES Black citizens [31,32]. Additionally, only 1.5% of the \$1.6 billion awarded in post-Katrina FEMA contracts went to minority-owned businesses—3.5% less than is required under federal contracting rules [31]. In another example, disastrous flooding in Iowa in 2008 prompted federal property acquisitions in heavily-flooded areas through the FEMA Hazard Mitigation Grant Program (HMGP) and the US Department of Housing and Urban Development Community Development Block Grant (CDBG) program. Such acquisitions aim to mitigate future flood damage and facilitate recovery by compensating property owners based on pre-flood property values. However, evidence indicates that socially-disadvantaged groups have been inequitably compensated for their property relative to socially advantaged groups via buyout programs [33,34]. After the 2008 Iowa floods, Muñoz & Tate [34] found that higher Hispanic and elderly neighborhood composition predicted below-value compensation from HMGP and CDBG property buyouts. Similarly, Cutter and colleagues [35] found that predominately White and more affluent communities along the Mississippi Gulf Coast received disaster assistance funds and insurance settlements faster than minority and low-income communities after Katrina. In another study, census tracts in South Carolina with higher levels of per capita income received significantly greater FEMA Individual Assistance (IA) funds after Hurricane Joaquin [36]. While most studies focus on SES and race/ethnicity, a national study at the county level found that an increase in the percentage of children in two-parent households was associated with a decrease in the likelihood of receiving federal Public Assistance (PA) funds for disaster-impacted public infrastructure repairs [37]. Other research shows that some social groups are less likely to pursue and thus receive post-disaster assistance from government sources. For example, undocumented immigrants (as well as their family members, friends, and neighbors with legal US residency status) may experience exclusion from government assistance due to programmatic restrictions and ever-present fears regarding deportation [38,39].

Social disparities in disaster assistance extend beyond government sources. For example, in the NGO space, the ARC and faith-based groups are key players. While the ARC has an official commitment to political

impartiality with a goal of universality, in practice, this has led to a colorblind approach resulting in neglect of communities of color and an oppressive workplace culture. This caused public backlash, leading the ARC to respond with a push for organizational diversity that many observers perceived as a superficial strategy to counteract allegations of racial insensitivity [40]. As for religious organizations, research indicates that the composition of a congregation and its affiliated volunteers' tendencies to identify with particular disaster survivors (e.g., based on perceived similarities) can influence how they provide assistance. For example, a large Black Methodist church in Houston effectively assisted Katrina evacuees who were homeless, largely due to their own experience with homeless members in their congregation; meanwhile, other Houston religious organizations did not as effectively address the needs of homeless Katrina survivors [26].

Aid from social networks may also be unevenly disbursed, with some experiencing neglect due to their generally disadvantageous social connections. For example, isolation caused by cultural "othering" practices within one's neighborhood may reduce access to assistance after disasters; such a situation affected rural female Thai immigrants impacted by the Great East Japan Earthquake and Tsunami of 2011 [41]. Additionally, the social networks of affluent individuals typically provide greater access to a variety of resources for recovery compared to minority and low-income people's social networks, which often circulate less information and typically have lower capacity to confer supportive resources [28,29,42,43]. In terms of private businesses, large corporations (i.e., NRG Energy, ExxonMobil, AT&T, Walmart, etc.) donated millions of dollars for Harvey relief efforts.

A few prior studies suggest that disparities in the receipt of assistance based on minority race/ethnicity and low-to-mid SES may translate into less extensive recovery, although this question has not been directly investigated. A post-Katrina study found that New Orleans residents in the middle range of social vulnerability experienced the slowest recovery. This was because assistance programs focused on the most vulnerable and the least vulnerable utilized their extensive private resources [44]. Bolin and Stanford [45] noted that unmet needs (and stunted recovery) after disasters typically result from two related phenomena: the depth of already existing social inequalities that create vulnerable populations, and inadequacies in institutionalized disaster-assistance programs from governments and disaster NGOs. This appears to have been relevant following Harvey, wherein evidence suggests there was an

unequal distribution of monetary assistance in Southeast Texas after the event. Smaller, whiter, more affluent towns were provided far greater recovery funds per capita than more populous, poorer, majority-minority cities, reflecting Texas' problematic aid designation formula, which weighs geographical and political subdivisions over population size and areas most in need [46]. While a change in wealth is not equivalent to recovery, Howell and Elliott [11] found that FEMA post-disaster assistance exacerbated rather than ameliorated wealth inequalities between Black and White households. To our knowledge, however, it remains untested whether the receipt of assistance actually improves disaster survivors' near-term recovery prospects, since most prior research has simply assumed the existence of a causal link between assistance and recovery.

In this study, we examine social disparities in post-Harvey assistance and near-term recovery for a population-based sample of Greater Houston households (see Fig. 1), and the influence that receiving assistance had on the extent of households' near-term recovery. Our study's research objectives are as follows: (1) analyze relationships between social vulnerability variables and the receipt of recovery assistance from (a) all sources and specifically from (b) government or (c) NGO sources; and (2) examine how social vulnerability variables and the receipt of assistance influenced the extent of near-term household recovery.

2. Materials and methods

2.1. Data collection

We collected data from a random sample of households in the Greater Houston study area between November 29-December 22, 2017 and January 2-6, 2018. Institutional Review Boards of the University of Texas at El Paso and University of Utah both approved the study, and survey respondents provided verbal consent to participate. Fig. 2 depicts the data collection process for the survey. The sampling frame consisted of Greater Houston residents whom we contacted (N = 1240). First, using random-digit dialing within a random sample of cellular telephone numbers across the study area, interviewers from a survey research firm screened respondents for eligibility. Eligibility was based on permanent residence in Greater Houston at the time of Hurricane Harvey (August 25, 2017), spoken command of Spanish or English, being at least 18

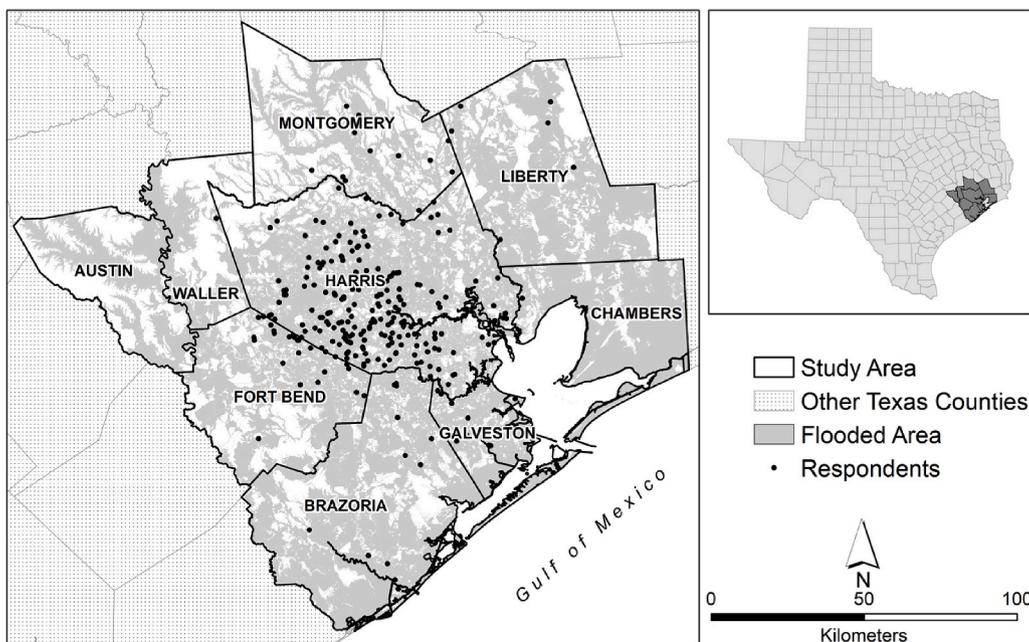


Fig. 1. Greater Houston, Texas, with counties, survey respondents, and Hurricane Harvey flooded area, 2017.

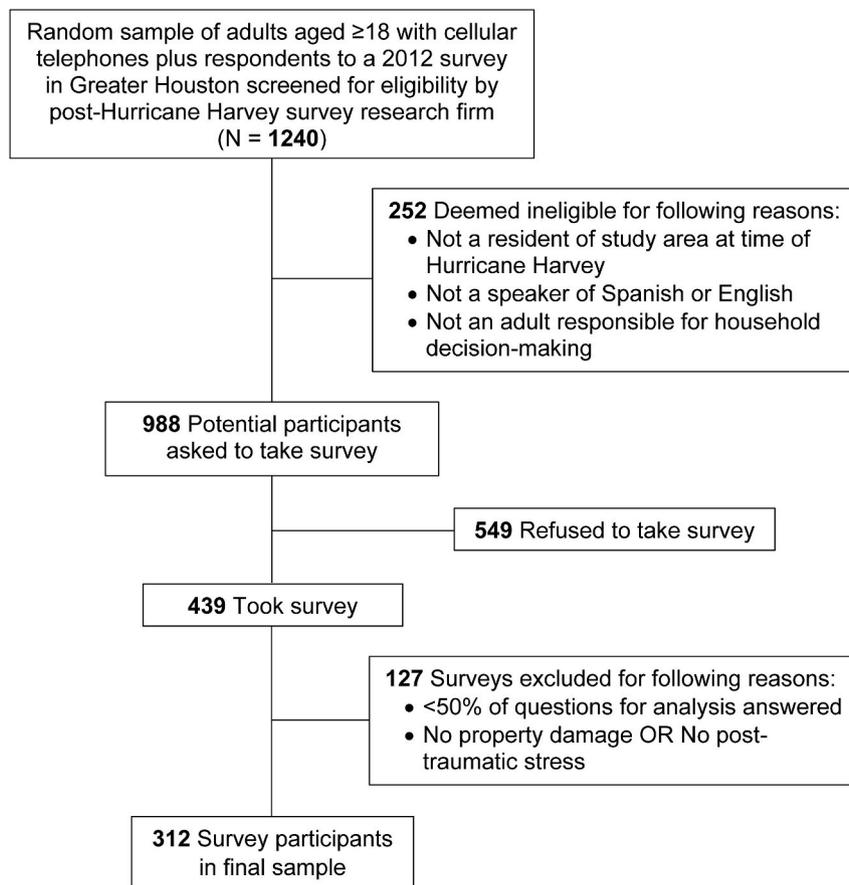


Fig. 2. Data collection process for the post-Hurricane Harvey survey in Greater Houston, Texas, 2017.

years old, and having (at least partial) responsibility for household decision-making. Cellular telephone numbers were important because they allowed us to reach persons who had relocated (temporarily or permanently) because of Harvey [47]. Respondents could take the survey by cellular telephone in English or Spanish. We augmented the sample by contacting respondents to a representative, probability-based survey focused on flood hazards conducted in 2012; we updated their contact information and re-contacted them as part of our 2017 post-Harvey survey, inviting them first to complete the survey online before calling non-respondents by telephone [48,49].

Of 988 eligible respondents we contacted, 439 (44.4%) took the survey: 368 were new respondents from the cellular telephone sample and 71 were re-surveyed respondents who also completed the 2012 survey [48]. This calculation follows the American Association for Public Opinion Research [50] Cooperation Rate 2 guidelines. We excluded 127 respondents who did not complete at least 50% of the survey items relevant to this analysis, had no property damage, or had no post-traumatic stress (PTS) symptoms (i.e., a PCL-S checklist score of 17), resulting in a final analysis n of 312. We based the decision to exclude those with no property damage or PTS symptoms on the assumption that respondents had to experience measurable impacts to need post-disaster assistance or to undertake a process of near-term recovery. This step was necessary as some Greater Houston area residents captured in our survey sample were relatively unaffected by Harvey.

Study participants were generally representative of Greater Houston adult residents in terms of age, race/ethnicity, and income. The median age of survey participants was 49 years, and the average adult population age in Greater Houston was 46 years. Study participants were 30% non-Hispanic White, 40% Hispanic/Latino, and 17% non-Hispanic Black, while the adult population in Greater Houston was 36% Non-Hispanic White, 37% Hispanic/Latino, and 17% non-Hispanic Black.

Survey participants' average annual household income was \$63,795, with the 2017 median annual household income for Greater Houston being \$60,902.

We adapted our instrument from survey instruments previously utilized in post-disaster flood research [14,51–54]. For our analysis, we utilized data from the survey pertaining to social vulnerability, the receipt of post-disaster assistance, near-term recovery, as well as other Harvey experiences.

2.2. Dependent variables

To address our first research objective, we utilized three variables: (1) receipt of assistance from any source, (2) receipt of government assistance, and (3) receipt of NGO assistance. Descriptive statistics for these variables are in Table 1. We created the “assistance from any source” variable using four survey questions addressing different sources of disaster recovery assistance a household may have obtained. These assistance sources included government assistance, NGO assistance, assistance from a private business, and assistance from one’s own social network. Examples of the types of assistance providers included in each source were indicated as part of the survey question (shown in Table 1 under “Survey Question” heading). We did not ask respondents to specify the specific source of assistance they received (e.g., ARC vs. Salvation Army). If a respondent answered “yes” to receiving assistance from any or several of the four possible sources, they were coded as a 1, with no assistance received from any listed source being coded as a 0. Nearly one-half of households reported receiving any assistance. We created separate government and NGO assistance variables using responses to those specific survey items, because they were the most common sources of assistance in our survey. We coded each of these variables dichotomously, with 0 indicating a household did not receive

Table 1
Survey questions and descriptive statistics (original data) of variables analyzed^a.

| Variable | Survey Question | Metric | Mean | n | Range | Std. Dev. | % Missing |
|--|---|---|-------|--------------------------|--------|-----------|-----------|
| Any Assistance ^b | Sum of 4 measures ^c | 0 = No 1 = Yes | 0.46 | 160 (0) 138 (1) | 0 - 1 | 0.50 | 4.5 |
| Government Assistance ^b | Did your household receive any type of assistance after Hurricane Harvey from a government organization, such as the Federal Emergency Management Agency, the State of Texas, your City government, or your County government? | 0 = No 1 = Yes | 0.29 | 213 (0) 86 (1) | 0 - 1 | 0.45 | 4.2 |
| Non-government Assistance ^b | Did your household receive any type of assistance after Hurricane Harvey from a voluntary, non-profit, non-governmental organization, such as the Red Cross, the Salvation Army, a church- or faith-based group, or a neighborhood- or community-based organization? | 0 = No 1 = Yes | 0.22 | 234 (0) 67 (1) | 0 - 1 | 0.42 | 3.5 |
| Near-term Recovery | To what extent has your household recovered from the impacts of the disaster? Please select a number on a scale ranging from 1 to 10, with 1 meaning that your household "has recovered very little" and 10 meaning your household "has recovered completely". | 1 = has recovered very little — 10 = has recovered completely | 7.13 | 296 | 1 - 10 | 3.16 | 5.1 |
| Hispanic Foreign-born non-citizen | Determined based on 3 survey measures ^d | 0 = No 1 = Yes | 0.21 | 240 (0) 63 (1) | 0 - 1 | 0.41 | 2.9 |
| Hispanic Foreign-born US citizen | Determined based on 3 survey measures ^d | 0 = No 1 = Yes | 0.09 | 277 (0) 26 (1) | 0 - 1 | 0.28 | 2.9 |
| Hispanic US-born | Determined based on 3 survey measures ^d | 0 = No 1 = Yes | 0.11 | 279 (0) 33 (1) | 0 - 1 | 0.31 | 0 |
| Non-Hispanic Black or African American | (A) Are you of Hispanic, Latino, or Spanish origin? "No" (B) Which of the following best describes your race? | 0 = No 1 = Yes | 0.17 | 252 (0) 53 (1) | 0 - 1 | 0.38 | 2.2 |
| Non-Hispanic Multiracial/Other Race | (A) Are you of Hispanic, Latino, or Spanish origin? "No" (B) Which of the following best describes your race? ^e | 0 = No 1 = Yes | 0.06 | 293 (0) 19 (1) | 0 - 1 | 0.24 | 0 |
| Children in Household | For all other members of your household, not including yourself, how many are currently ... ? (A) 4 years old or younger (B) 5–17 years old | 0 = No (0 children) 1 = Yes (≥1 children) | 0.51 | 142 (0) 149 (1) | 0 - 1 | 0.50 | 6.7 |
| Unemployed | At the time of Hurricane Harvey, for all adult members of your household – 18 years of age and older, including yourself, how many were ... unemployed? | 0 = No (0 members) 1 = Yes (≥1 member) | 0.52 | 136 (0) 148 (1) | 0 - 1 | 0.50 | 9.0 |
| Retired | At the time of Hurricane Harvey, for all adult members of your household – 18 years of age and older, including yourself, how many were ... retired? | 0 = No (0 members) 1 = Yes (≥1 member) | 0.30 | 196 (0) 86 (1) | 0 - 1 | 0.46 | 9.6 |
| Income | What was your total household income for the year 2016 before taxes? | 1 = < \$10,000 2 = \$10,000 - \$20,000 3 = \$20,000 - \$30,000 4 = \$30,000 - \$40,000 5 = \$40,000 - \$50,000 6 = \$50,000 - \$75,000 7 = \$75,000 - \$100,000 8 = \$100,000 - \$150,000 9 = \$150,000 - \$250,000 10 = > \$250,000 | 4.81 | 281 | 1 - 10 | 2.68 | 9.9 |
| Disability | (A) Because of a physical, mental or emotional health condition, did you need any special assistance during Hurricane Harvey in order to evacuate your home and get to a safe place? (B) How many other members of your household not including yourself needed any special assistance during Hurricane Harvey in order to evacuate your home because of a physical, mental or emotional health condition? | 0 = No (0 members) 1 = Yes (≥1 member) | 0.15 | 221 (0) 38 (1) | 0 - 1 | 0.36 | 17.0 |
| PTS Symptoms | | | 30.49 | 285 | | 14.67 | 8.7 |

(continued on next page)

Table 1 (continued)

| Variable | Survey Question | Metric | Mean | n | Range | Std. Dev. | % Missing |
|--------------------|--|--|------|-------------------|---------|-----------|-----------|
| | Respondent was asked 17-items related to experiencing PTS symptoms from the PCL-S and a composite score was calculated ^f | Sum of 17 measures ^f : 1 = Not at all affected 2 = A little bit affected 3 = Moderately affected 4 = Quite a bit affected 5 = Very much affected | | | 17 - 85 | | |
| Property Damage | Was the home you were living in at the time of Hurricane Harvey “completely destroyed”, “seriously damaged”, “damaged to a limited degree”, damaged to a minor degree”, or “not damaged at all”? | 1 = Not damaged at all 2 = Minor damage 3 = Limited damage 4 = Serious damage 5 = Completely destroyed | 2.09 | 300 | 1 - 5 | 1.08 | 3.8 |
| Contents Insurance | Were the contents of the home you lived in at the time of Hurricane Harvey covered by a National Flood Insurance Program policy? | 0 = No 1 = Yes | 0.23 | 225 (0) 68 (1) | 0 - 1 | 0.42 | 6.1 |

^a Cases where level of property damage was zero or composite score on PTS scale was 17 were not included in the analysis.
^b Types of assistance include: debris removal; construction materials; tools; cleanup or repairs; clothing; food or water; moving or storage; living expenses; furnishings; medical aid; loans; donations; income tax deductions; counseling or advice; unemployment, transportation or housing assistance; Lone Star; veteran’s benefits; or any other forms of aid that you needed after the disaster.
^c Respondent selected “yes” to receiving assistance from one or more of these sources: (A) a government organization, (B) a voluntary, non-profit, non-governmental organization, (C) a private business, or (D) your own social networks, including your family members, friends, neighbors, or co-workers.
^d Respondent selected “yes” or “no” accordingly to three questions: (A) Are you of Hispanic, Latino, or Spanish origin? (B) Were you born (1) in the United States (2) outside the United States? (C) Are you a citizen of the United States?
^e Respondent selected “yes” for one or more of the following races: (A) American Indian or Alaskan Native, (B) Asian, (C) Pacific Islander, or (D) some other race. Respondent did not select “yes” for Black or African American.
^f Items on the PCL-S PTSD Checklist: (A) Bothered by repeated, disturbing memories, thoughts, or images of Hurricane Harvey? (B) Bothered by repeated, disturbing dreams of Hurricane Harvey? (C) Bothered by suddenly acting or feeling as if Hurricane Harvey was happening again - as if you were reliving it? (D) Feeling very upset when something reminded you of Hurricane Harvey? (E) Having physical reactions – that is, heart pounding, trouble breathing, sweating – when something reminded you of Hurricane Harvey? (F) Avoiding thinking about or talking about Hurricane Harvey or avoiding having feelings related to it? (G) Avoiding activities or situations because they reminded you of Hurricane Harvey? (H) Having trouble remembering important parts of Hurricane Harvey? (I) Loss of interest in activities that you used to enjoy? (J) Feeling distant or cut off from other people? (K) Feeling emotionally numb or being unable to have loving feelings for those close to you? (L) Feeling as if your future will somehow be cut short? (M) Trouble falling or staying asleep? (N) Feeling irritable or having angry outbursts? (O) Having difficulty concentrating? (P) Being “super-alert” or watchful or on guard? (Q) Feeling jumpy or easily startled.

assistance from the source, and 1 indicating a household did receive assistance from the source. More households received governmental assistance (29%) than non-governmental assistance (22%). While private business or social network assistance are included in the “any source” variable, we did not analyze them as separate variables due to small counts.

For our second research objective, we analyzed the extent of near-term recovery utilizing a survey question that asked responding householders to indicate the extent to which their household had recovered from the impact of the disaster on a scale from 1 to 10, with 1 meaning they had recovered very little and 10 meaning they had recovered completely. The average householder rated their household a 7, suggesting partial recovery (see Table 1). All survey responses were collected within four months of Harvey’s landfall on the Texas coast, a timeframe consistent with near-term (i.e., short-term and intermediate) recovery as defined by the FEMA [25].

2.3. Independent variables

We constructed independent variables gauging different aspects of social vulnerability. Descriptive statistics for independent variables are in Table 1. While we examined social vulnerability variables separately, composite social vulnerability indices—specifically, Cutter and colleagues’ “SoVI” [55] and the US Centers for Disease Control’s (CDC)

“SVI” [56]—provided points of reference for selecting indicators generally relevant to disparities in post-disaster assistance and recovery in the US. Earlier empirical studies of social vulnerability in disaster events informed the development of each social vulnerability index [55, 56], but few studies have validated either index in reference to actual post-disaster outcomes. One such study found that these social vulnerability indices were predictive of FEMA IA applications, damaged housing units, and property loss after Hurricane Sandy [57].

We used each independent variable in analyses addressing both research objectives. Additionally, we used the receipt of any assistance variable (described above) as an independent variable in our second research objective analysis, to examine whether receiving assistance influenced the extent of near-term recovery. We constructed a categorical variable that combined race/ethnicity, nativity, and citizenship survey data. It included Hispanic foreign-born non-citizen; Hispanic foreign-born US citizen; Hispanic US-born; non-Hispanic Black or African American; and non-Hispanic, non-Black multiracial/other race. Non-Hispanic White served as the reference group. Each category was coded 1 = yes and 0 = no. We analyzed the Hispanic sample intra-categorically due to the social diversity of the large Hispanic population in Greater Houston. Foreign nativity and non-US citizenship are prominent sociopolitical axes of difference in the area and thus sources of social vulnerability that may serve as barriers to accessing assistance [17,18]. In the sample, 21% of respondents were foreign-born non-citizen

Hispanics, 9% were foreign-born citizen Hispanics and 11% were US-born Hispanics.

Other social vulnerability variables include the presence of children (ages < 18 years) in the household (0 = no children; 1 = one or more children). Half of surveyed households included children. In terms of employment status, variables for unemployment status and retirement status for any adult in the household were coded dichotomously (1 = yes; 0 = no), with households having all adult members employed being the reference group. We gauged unemployment and retirement status for any adult member of the household rather than for the householder because multiple earner household arrangements are more common in the US than no earner or single earner arrangements combined [58]. Half of households had at least one unemployed member and 30% had at least one retired member. We measured household income on a scale from 1 (low) to 10 (high), and mean household income was just below 5. We measured disability dichotomously based on whether any person in the household had a physical, mental, or emotional disability (coded 1) or not (coded 0) and 15% of households included someone with a disability.

We included additional independent variables related to receipt of assistance and recovery. These included a PTS variable constructed using respondents' answers to the 17-item PCL-S checklist, a standardized screening assessment for PTSD [59]. Table 1 lists each of the PCL-S checklist items. Each item on the checklist had a possible score ranging from 1 (not bothered) to 5 (bothered very much). We calculated composite scores on a continuous scale ranging from 17 to 85, as per prior research [60]; the average score in this sample was 30. We included the level of property damage to the household's home as a continuous variable gauged by householder self-reporting on a scale from 1 (not damaged at all) to 5 (completely destroyed). The average household reported a score of 2 or "minor damage." Finally, we included a dichotomous variable for whether households maintained insurance through the National Flood Insurance Program (NFIP) for contents in their homes (1 = yes; 0 = no), as this was applicable to both owner- and renter-occupants. Nearly one-quarter of households had NFIP contents insurance.

2.4. Statistical approach

We started by using multiple imputation, which is a best practice for reducing bias when analyzing data with missing values due to survey non-response [61–64]. The "% Missing" column in Table 1 reports the percentage of missing values for each variable in the original data set. The percentage of respondents with missing information for our variables ranged from 0% for non-Hispanic Black and multiracial/other race to 17.0% for disability (Table 1). Following convention [61], we performed multiple imputation to create 20 data sets with imputed values for all missing data points. We specified all ordinal variables as continuous. This is recommended in the multiple imputation literature because rounding imputed values to conform to discrete ordinal variable specifications results in more biased parameter estimates in multivariable models [61,65,66]. We report pooled results from analyses across the 20 imputed datasets, which we calculated according to Rubin's [63] rules for pooling.

To address research objective one, we report pooled results from binary logistic generalized linear models that predict the three dichotomous recovery assistance dependent variables. For research objective two, we report pooled results from a generalized linear model with a normal distribution and identity link function that predicts the continuous near-term recovery extent dependent variable. We tested generalized linear models to address research objective two using inverse Gaussian, gamma, and Tweedie distributions with identity and logarithmic link functions to predict near-term recovery extent. Results from those models were similar to the model we report here, but Akaike information criterion (AIC) values indicated better fit for the normal distribution with identity link function specification. We conducted all

analyses using IBM SPSS 25.0.0.

3. Results

3.1. Research objective 1

Table 2–A presents results from the generalized linear model predicting household receipt of assistance from any source. US-born Hispanics had 350% greater odds of receiving assistance from any source compared to non-Hispanic Whites (95% CI = 1.69–12.01, $p = 0.003$). Greater PTS symptoms and levels of property damage were positively associated with receiving any assistance. Each one unit increase in PTS symptom score increased the odds of receiving assistance by 2% (95% CI = 1.00–1.04, $p = 0.035$). The odds of receiving any assistance increased by 123% for every one unit increase on the property damage scale (95% CI = 1.67–2.98, $p < 0.001$).

Table 2–B shows results from the model predicting receipt of government assistance. Households with dependent children had 138% greater odds (95% CI = 1.24–4.57, $p = 0.009$) of receiving government assistance compared to households without children. A unit decrease in the level of household income increased the odds of receiving government assistance by 13% (95% CI = 0.77–0.996, $p = 0.043$). Each additional unit on the property damage scale increased the odds of

Table 2
Generalized binary logistic models predicting receipt of (A) Any assistance, (B) Government assistance, and (C) Non-government (NGO) assistance ($n = 312$).

| Variable | (A) Any Assistance | | (B) Government Assistance | | (C) NGO Assistance | |
|-----------------------------------|----------------------|------|---------------------------|------|----------------------|------|
| | OR (95% CI) p | SE | OR (95% CI) p | SE | OR (95% CI) p | SE |
| Foreign-born non-citizen Hispanic | 0.98 (0.42, 2.27) | 0.43 | 1.21 (0.48, 3.02) | 0.47 | 0.96 (0.35, 2.60) | 0.51 |
| Foreign-born US citizen Hispanic | 2.13 (0.79, 5.75) | 0.51 | 2.30 (0.78, 6.81) | 0.55 | 0.77 (0.19, 3.13) | 0.71 |
| US-Born Hispanic | 4.50 (1.69, 12.01)** | 0.50 | 2.05 (0.74, 5.64) | 0.52 | 2.07 (0.71, 6.03) | 0.55 |
| Non-Hispanic | 1.16 (0.52, 2.59) | 0.41 | 1.69 (0.72, 3.99) | 0.44 | 1.59 (0.66, 3.83) | 0.45 |
| Black or African American | 1.54 (0.48, 4.89) | 0.59 | 1.70 (0.46, 6.22) | 0.66 | 0.52 (0.10, 2.63) | 0.83 |
| Multiracial/Other Race | 1.52 (0.84, 2.73) | 0.30 | 2.38 (1.24, 4.57)** | 0.33 | 2.28 (1.10, 4.74)** | 0.37 |
| Children in Household | 0.89 (0.50, 1.56) | 0.29 | 1.17 (0.63, 2.15) | 0.31 | 1.67 (0.84, 3.32) | 0.35 |
| Unemployed | 0.76 (0.41, 1.44) | 0.32 | 0.84 (0.42, 1.68) | 0.36 | 0.94 (0.45, 1.98) | 0.38 |
| Retired | 0.91 (0.81, 1.03) | 0.06 | 0.87 (0.77, 0.996)* | 0.07 | 0.97 (0.84, 1.11) | 0.07 |
| Income | 0.78 (0.35, 1.69) | 0.40 | 0.57 (0.25, 1.31) | 0.42 | 0.37 (0.15, 0.93)* | 0.47 |
| Disability | 1.02 (1.00, 1.04)* | 0.01 | 1.01 (0.99, 1.03) | 0.01 | 1.03 (1.01, 1.05)** | 0.01 |
| PTS Symptoms | 2.23 (1.67, 2.98)*** | 0.15 | 2.23 (1.66, 2.99)*** | 0.15 | 1.77 (1.29, 2.42)*** | 0.16 |
| Property Damage | 0.67 (0.33, 1.34) | 0.36 | 1.21 (0.58, 2.55) | 0.38 | 0.58 (0.25, 1.37) | 0.44 |
| Contents Insurance | | | | | | |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Note: Models used a normal distribution with an identity link function.

receiving government assistance by 123% (95% CI = 1.66–2.99, $p < 0.001$).

We report results for the model predicting receipt of NGO assistance in Table 2–C. Households with children had 125% greater odds (95% CI = 1.10–4.74, $p = 0.028$) of receiving NGO assistance relative to childless households. Having a person with a disability in the household decreased a household’s odds of receiving assistance from a NGO source by 63% (95% CI = 0.15–0.93, $p = 0.034$). Each unit increase in the householder’s PTS score increased the odds of receiving NGO assistance by 3% (95% CI = 1.01–1.05, $p = 0.003$). Each unit increase in the level of property damage increased the odds of receiving NGO assistance by 77% (95% CI = 1.29–2.42, $p < 0.001$).

3.2. Research objective 2

Table 3 reports results from the generalized linear model predicting the extent of near-term household recovery following Hurricane Harvey. The receipt of assistance from any source was not predictive of the extent of near-term recovery. In terms of the social vulnerability variables, each one unit increase on the income scale was associated with a 0.22 increase on the 10-point extent of recovery scale (95% CI = 0.09–0.36, $p = 0.001$). Having a person with a disability in the household was associated with a 1.01-point decrease in extent of near-term recovery (on the 10-point scale) compared to households without persons with disabilities (95% CI = –1.98 to –0.03, $p = 0.043$). Each unit increase in the householder’s PTS score was associated with a 0.03 decrease in the extent of recovery (95% CI = –0.06 to –0.01, $p = 0.001$). Additionally, each one unit increase in the level of property damage was associated with a 1.13 decrease on the 10-point recovery scale (95% CI = –1.45 to –0.82, $p < 0.001$).

4. Discussion

To address our first research objective, we analyzed the relationship between social vulnerability and receipt of post-disaster assistance. The social vulnerability variables were not highly predictive of households’ receiving less assistance following Harvey, with one notable exception pertaining to disability. In fact, three findings showed that more socially vulnerable groups were more likely to receive assistance. (1) US-born Hispanics exhibited greater odds than non-Hispanic Whites of receiving any assistance. Since there were no associations for US-born Hispanics with government or NGO assistance alone, we infer that this finding was partly attributable to assistance received from social networks. We speculate that Hispanic cultural emphases on family relations led to relatively higher levels of post-disaster resource sharing via social

Table 3
Generalized linear model predicting near-term recovery ($n = 312$).

| Variable | Coefficient (95% CI) p | SE |
|---|--------------------------|------|
| Received Any Assistance | –0.05 (–0.72, 0.62) | 0.34 |
| Foreign-born non-citizen Hispanic | 0.19 (–0.77, 1.15) | 0.49 |
| Foreign-born US citizen Hispanic | 0.08 (–1.07, 1.23) | 0.59 |
| US-Born Hispanic | 0.00 (–1.06, 1.07) | 0.54 |
| Non-Hispanic Black or African American | –0.01 (–0.91, 0.90) | 0.46 |
| Multiracial/Other Race (Non-Hispanic & Non-Black) | 0.51 (–0.72, 1.74) | 0.63 |
| Children in Household | –0.48 (–1.15, 0.18) | 0.34 |
| Unemployed | –0.48 (–1.13, 0.18) | 0.33 |
| Retired | 0.01 (–0.69, 0.70) | 0.35 |
| Income | 0.22 (0.09, 0.36)** | 0.07 |
| Disability | –1.01 (–1.98, –0.03)* | 0.49 |
| PTS Symptoms | –0.03 (–0.06, –0.01)** | 0.01 |
| Property Damage | –1.13 (–1.45, –0.82)*** | 0.16 |
| Contents Insurance | 0.17 (–0.57, 0.91) | 0.38 |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Models used a normal distribution with an identity link specification.

networks. This may have only been applicable to US-born Hispanics due to more deeply rooted and resource-rich networks for sharing compared to Hispanic immigrants (foreign-born), who often have left such networks behind. (2) We found that households with children were more likely to receive assistance from government and NGO sources, which they were likely in greater need of compared to households without dependents. (3) As household income decreased, the odds of receiving assistance increased, most notably in the case of government assistance. While we did not expect these findings based on the social vulnerability to hazards/disasters literature (with the exception of Finch and colleagues [44]), they indicate that assistance after Harvey was generally distributed equitably based on race/ethnicity and targeted households with children and lower incomes. In sum, these findings suggest that post-disaster assistance was distributed by some types of organizations in a manner that prioritized particular vulnerable groups, and at a population-level, the provision of assistance did not generally compound disadvantages experienced by socially vulnerable households. This finding is encouraging from a vulnerability reduction perspective.

Less encouraging from a social vulnerability perspective was our finding that households including people with disabilities were less likely to receive post-disaster assistance from all of the sources we examined, most notably in the case of NGO assistance. Our finding for constrained access to post-disaster assistance based on disability is particularly concerning since disability status was associated with more extensive flooding across Greater Houston neighborhoods in Hurricane Harvey [3], suggesting that people with disabilities suffered disproportionate impacts. It is plausible that NGOs in particular may have inadequately trained their volunteer assistance providers in addressing the post-disaster needs of those with disabilities [23,67–70], which may have inadvertently constrained access to assistance for this socially vulnerable group. In terms of practical implications, well-maintained digital directories with locational and contact information for disabled populations within high-risk zones could allow volunteer assistance providers to better assess and address the needs of disabled populations in future disasters.

We found that levels of property damage and householder PTS were predictive of receiving post-disaster assistance across multiple assistance sources. This was not surprising given that we analyzed a representative sample of Greater Houston area residents affected to varying degrees by a large-scale disaster. Generally, those findings indicate efficient aid provision, since households that experienced more severe disaster impacts were more likely to receive assistance.

To address our second research objective, we examined how social vulnerability and the receipt of assistance influenced households’ extent of near-term recovery from Hurricane Harvey. For our social vulnerability variables, we found that as household income increased, the extent of near-term recovery increased. We expected this finding based on the social vulnerability literature [5,6,8], and it suggests that lower-income households experienced less extensive near-term recovery based on their reduced capacities to meet the demands of recovery. We also found that households including people with disabilities experienced less extensive near-term recovery than those without. This aligns with the literature on disability in disaster, wherein this socially vulnerable population has been found to disproportionately experience other disaster-related impacts, e.g., more extensive flooding, property loss, constrained access to shelter, and/or increased morbidity and mortality [3,23,71–74]. Finally, we found that households with greater property damage and householders with greater PTS experienced less extensive near-term recovery after Harvey. Rivera [75] found something similar with respect to Harvey-induced property damage predicting worse short-term recovery. This pattern is likely attributable to the fact that increased damage and trauma pose greater challenges in the recovery process.

Importantly, we found that the receipt of any post-disaster assistance was not predictive of the extent of near-term household recovery. We did not expect that finding, because it is conventionally assumed in the hazards and disasters literature that the provision of post-disaster

assistance contributes to recovery. Our results, however, do not support that expectation. Instead, our findings dovetail with prior research that has documented some disaster survivors receiving ineffective disaster assistance [76,77]. In shelters for Hurricane Sandy, occupants experienced intensified anxiety, frustration, depression, and exhaustion due in part to shelters' lack of medical resources, counseling services and procedures to aid transitions out of the shelter [76]. Our findings indicate that recovery from Harvey is an ongoing process, one likely to continue to be experienced differentially in the future based on the extent of damage, the varying levels of economic resources at a households' disposal, and experiences of disability.

Our study findings highlight the need for greater post-disaster assistance to remediate property damage and address mental health impacts, especially for disaster survivors of low SES, in order to facilitate recovery. Greater investment in pre-event flood hazard mitigation and disaster preparedness initiatives is warranted, since post-disaster assistance was not an influential determinant of recovery. Grineski and colleagues [49] found that undertaking more pre-event hazard mitigation actions at home sites (e.g., elevating electrical components of home structures above flood height, installing hurricane shutters) was associated with fewer physical health problems and adverse event experiences, lower PTS, and faster recovery after Harvey. Implementing flood and hurricane mitigation measures is costly, which underscores the need for increased government investment in targeted programs to stimulate wider adoption of such hazard adjustments.

In terms of increasing preparedness, our findings highlight the need for improved pre-event disaster planning among mental health care providers—with a focus on broadening access for socially vulnerable populations—in order to more comprehensively treat population trauma in the aftermath of disasters. Because disability status emerged from our study as a key determinant of social vulnerability, it should receive special attention in disaster preparedness planning in Greater Houston and beyond. Maintaining easily accessible digital directories would enable assistance providers to more effectively identify disabled disaster survivors and meet their particular needs. In sum, our findings underscore the importance of pre-event hazard mitigation and preparedness, as well as targeted provision of post-disaster assistance, for establishing conditions more conducive to recovery. This is in general alignment with the consensus perspective among scholars of hazards and disasters [78–80]—that is, pre-event risk reduction is more effective in reducing population impacts and facilitating recovery than waiting to pick up the pieces in the aftermath of events.

4.1. Limitations and future research

Due to our reliance on self-reported survey data, our inferences depend on participants' recall of past events, for example, regarding the extent of their own recovery following Hurricane Harvey. Recall bias is inevitable in survey self-reports. However, surveying householders was our best available method to gain direct knowledge regarding the status of the household prior to and soon after Harvey. By surveying residents relatively soon after Harvey (within four months), we mitigated recall bias to the best of our ability. In addition, there was potential selection bias in our survey. Based on our survey design and administration, we failed to capture particular demographic segments that may have been particularly vulnerable to Hurricane Harvey, e.g., households without cellular telephones and those wherein householders spoke neither English nor Spanish. Our survey, however, was probability-based and our sample is generally representative of the Greater Houston population. In fact, our study sample has greater representativeness than samples used in prior published research on human dimensions of Hurricane Harvey, which have relied on convenience sampling from specific locations (e.g., shelters) or online crowdsourcing applications (e.g., Amazon Mechanical Turk, Qualtrics Panel).

We did not examine all dimensions of social vulnerability that potentially influenced access to assistance and near-term recovery.

Future research on those outcomes should examine gender and veteran status, among other potentially relevant axes of social vulnerability. Future studies should also examine specific assistance program requirements and tailor the selection of social vulnerability measures accordingly. For example, because housing assistance from FEMA's IA program targets homeowners, owner-occupancy vs. renter-occupancy should receive focus in any analysis of that particular program. Additionally, future post-disaster studies on the efficacy of specific types of assistance (e.g., debris cleanup, financial aid, etc.) are needed to document best practices and, ultimately, to improve allocation of resources such that households are enabled to recover more quickly and fully. Finally, future research would also benefit from the use of pre-/post-disaster data collection approaches to assessing household disaster recovery, although such study designs are often impracticable.

5. Conclusion

Our findings support three conclusions regarding post-disaster assistance provision and recovery efforts following Hurricane Harvey, which have implications for risk reduction in the context of future climate change-related extreme events in Greater Houston. First, post-Harvey assistance was received by households generally efficiently and equitably; efficiently in that those suffering greater property damage and trauma had higher odds of receiving aid, and equitably in that we found no disparities based on minority racial/ethnic or low socioeconomic statuses. In fact, particular socially vulnerable groups—such as households with children, US-born Hispanic members, or lower incomes—had greater odds of receiving assistance. Those findings are encouraging from a post-disaster vulnerability reduction perspective. Second, concerning social vulnerability, households with members of disabled status had lower odds of receiving aid, which is problematic given their increased exposure to Harvey-induced flooding [3]. Third, results from our analysis of near-term recovery raise concerns regarding efficacy and social vulnerability. The receipt of post-disaster assistance was not generally effective in addressing household recovery needs post-Harvey, and households with lower incomes and disability status experienced stunted near-term recovery, which highlights aspects of social vulnerability. Since floods in Greater Houston and other locales will increase in frequency and magnitude due to climate change [81,82], proactive steps are needed to enhance the efficacy of disaster risk reduction efforts in the study area and beyond in order to increase both the speed and equitability of post-disaster recovery. Delivery of effective post-event assistance, however, provides a necessary yet not sufficient basis for making recovery equitable, as interventions must also address salient dimensions of social vulnerability in pre-event hazard mitigation and disaster preparedness in order to achieve equitability. Finally, to inform practical efforts in the future, we must improve fundamental knowledge of relationships between pre-event risk reduction activities, post-disaster assistance, social vulnerability, and recovery.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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