Pre/Post Hurricane Surveys: Measuring Hurricane Preparation and Post Storm Impacts Using Geofencing Methods

Brassell, Thomas; Dayton, James; Kinder, Rachel[1]
[1]ICF, 126 College Street, Burlington, VT 05401 USA

Abstract

Disaster research presents a logistical and methodological challenge for survey research. In general, the short lead time between potential disaster identification and the experience of the disaster makes pre-disaster data collection through traditional probability methods a non-starter. Similarly, the time needed to obtain funds from government agencies to collect post-disaster data can result in studies fielding many months after the event, biasing the data. This paper reports on a novel approach to disaster research. Specifically, the utility of using mobile panel member geolocation to develop a sample frame of potential disaster survivors based on projected storm path, as well as actual disaster survivors.

In 2018, prior to Hurricane Florence, ICF fielded a pre-storm survey to a non-probability mobile panel using respondent geolocation to identify panel members within the storm's expected travel path. This pre-storm questionnaire asked about storm preparation, evacuation plans, previous hurricane experiences, and current health and psychological stress, and collected nearly 2,200 responses. Less than one month after Hurricane Florence, Hurricane Michael made landfall in the Florida panhandle as a category four hurricane prior to impacting many of the same areas impacted by Hurricane Florence. Subsequently, we launched a post-storm survey using mobile panel member geolocation to collect data from new panel members located within the actual travel path of both storms, along with recontacting the 2,200 pre-storm panel members. Our post-storm survey included many of the same measures as the pre-storm questionnaire, as well as questions about the impact of both hurricanes.

The data from both surveys provides important information regarding pre- and post-storm preparations, the extent and nature of damage, estimated cost of damage (covered and not covered by insurance), and evacuation information. We discuss the utility of using geolocation information from mobile panels to collect both pre- and post-disaster data, in conjunction with the major implications for the application of this methodology in disaster-related surveys.

Key Words: Geofencing, Geo-location Targeting, Mobile Panel, Disaster Recovery, Pre-Post Follow-up Survey, Psychological Stress Impacts

1. Background

Research has documented the negative physical and mental health impact to populations that have experienced various types of disasters (Lowe, et al., 2013; Bonanno, et al., 2010; Neria, Galea, & Norris, 2009; Neria, Nandi, & Galea, 2008, van Kamp et al., 2006). However, few studies have been able to examine how respondent-reported physical, and

mental health, including environment status, have changed after a disaster using a pre- and post-study methodology. This lack of research is not surprising given the unpredictable nature of disasters, challenges with respondent recruitment via probability sampling methods, and availability of research funding to conduct such studies. Non-probability studies represent a lower cost and more nimble opportunity to employ a pre- and post-disaster survey methodology, as well as explore the general utility of non-probability panels for disaster research.

Little research has been conducted regarding the use of non-probability panels in disaster research. In fact, to the knowledge of the authors of this paper, the 2017 non-probability post-disaster survey conducted in Houston, TX in the wake of Hurricane Harvey was the first ever of its kind. Non-probability panels offer an alternative survey methodology for post-disaster areas considering the logistical challenges and costs associated with constructing representative probability frames[1]. Specifically, non-probability studies offer solutions to the practical challenges of surveying in post-disaster areas, provided internet access is attainable[2]. Studies examining post-disaster media access have found smartphones to be the primary source connectivity to the internet[3], and the optimal communication path for post-disaster government aid[4]. Considering this past research, mobile panels, may offer the best method for obtaining responses post-disaster given the frequency of use of smartphone devises by the impacted population, and may further be able to account for population displacement.

In 2017, ICF worked with the Institute for Health Policy (IHP) at The University of Texas Health Science Center at Houston School of Public Health (UTHealth) to design a non-probability study to survey those impacted by the Hurricane Harvey in the Houston area. MFour, a non-probability mobile research panel organization, was contracted and panelists were sent the survey via the mobile app Surveys on the Go. The survey collected data regarding the impact of Hurricane Harvey to respondents, specifically asking about degree of damage to their home, flooding, evacuation, and mental and physical health since the storm. Data collected from just over 500 respondents was collected in just under two weeks. Panel respondents indicated flooding, damage to homes and vehicles, evacuation, and psychological distress as a result of Hurricane Harvey.

After the study in Houston, ICF used the MFour panelists once again to assess the utility of geotagging to measure post-disaster behavior. The Path 2 Purchase study integrated geotagging around home improvement stores to ask panelists what disaster-related materials they bought to fix damage caused by Hurricane Florence and Hurricane Michael. Responses were obtained from 250 respondents, collecting data regarding the financial impact Hurricane Michael and Hurricane Florence had on their household, and how much they spent at the store as a result of the hurricane(s). Importantly, because home improvement stores in the impacted regions were geocoded with a trigger radius built

[1] Kessler, R. C., Keane, T. M., Ursano, R. J., Mokdad, A., & Zaslavsky, A. M. (2008). Sample and design considerations in post-disaster mental health needs assessment tracking surveys. International Journal of Methods in Psychiatric Research, 17(Suppl 2), S6–S20. http://doi.org/10.1002/mpr.269.

[2] Hugelius, K., Adolfsson, A., Gifford, M., & Örtenwall, P. (2017). Facebook Enables Disaster Research Studies: The Use of Social Media to Recruit Participants in a Post-Disaster Setting. PLoS Currents, 9, ecurrents.dis.f4a444e1f182776bdf567893761f86b8.

[3] Kaigo, M. 2012. Social media usage during disasters and social capital: Twitter and the Great East Japan earthquake. Keio Communication Review, 34: 19–35.

[4] FEMA. (2013). National Strategy Recommendations: Future Disaster Preparedness. Washington, D.C.: Federal Emergency Management Agency.

around the stores, panel members who had entered the trigger radius received the opportunity to complete the survey. Utilizing this passive geotracking, we were able to identify panel members who had entered the geotagged area subsequent to the hurricane thru data collection.

The current study further expands on the utility of using a mobile panel as a data collection method in the wake of a disaster. By tracking Hurricane Florence and Hurricane Michael's path, we were able to geofence areas that presented a high probability of being impacted by the hurricanes. The focus of this study builds on the foundation of the 2017 Houston and Path 2 Purchase studies to further investigate the use of non-probability panels to perform disaster research.

2. Methodology

The study combined survey data from two waves of data collection to examine the impact of Hurricane Florence and Hurricane Michael. The first wave of data collection was before Hurricane Florence made landfall and geotargeted within the projected path of Hurricane Florence which involved parts of Virginia, North Carolina, South Carolina, and Georgia (Figure 1). A pre-disaster survey was administered through MFour's mobile app, Surveys on the Go, to panelists in the geotargeted locations over the course of a four-day period from September 13 to September 17 across coastal and non-coastal regional strata in the four states. The 2,186 respondents of the pre-disaster survey were asked questions to understand prior experience, preparation, impact, health, insurance, living characteristics (i.e. housing, income, and employment), and communication.

After Hurricane Florence and Hurricane Michael made landfall, the second survey was administered. The post-disaster survey built upon the pre-disaster survey and included questions about rescue, shortages, services, recovery, and need. Out of the 2,500 post-disaster respondents, 1,556 people were re-contacted participants, and 944 people were new contacts (Table 1). Respondents of the pre-disaster survey were re-contacted through their mobile device, regardless of their current location, and the disaster path of Hurricane Florence and Hurricane Michael (Figure 2 and Figure 3) was geofenced to recruit the new contacts to offset survey attrition. The locations of focus were Virginia, North Carolina, South Carolina, Georgia, and Florida with a fielding period of November 16 to December 3.

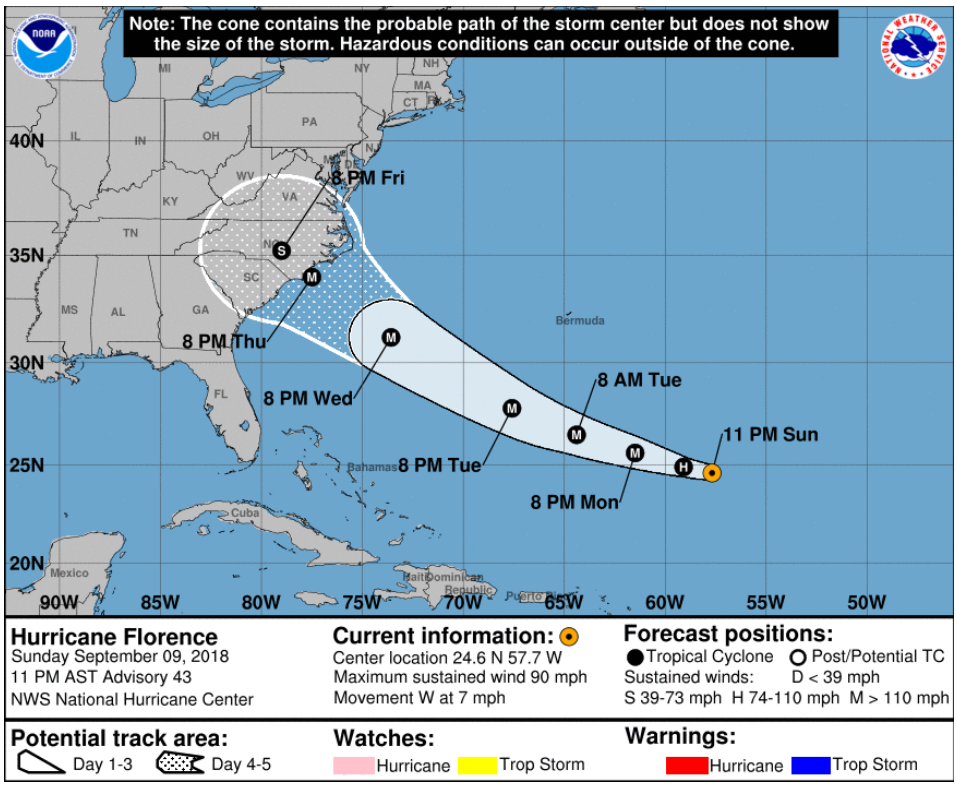

Figure 1: Hurricane Florence's Projected Route. From "FLORENCE Graphics Archive: 5-day Forecast Track and Watch/Warning Graphic," by the National Hurricane Center and Central Pacific Hurricane Center (http://www.nhc.noaa.gov/archive/2018/FLORENCE_graphics.php?product=5day_cone_no_line)

Table 1. Location Wave 1 and Wave 2 Respondents by State and Strata

Category	State	Count	Percent
Coastal	North Carolina	154	36.67%
	NC Recontact	93	37.20%
	South Carolina	146	34.76%
	SC Recontact	87	34.80%
	Georgia	120	28.57%
	GA Recontact	70	28.00%
Noncoastal	North Carolina	661	35.85%
	NC Recontact	375	39.27%
	South Carolina	648	35.14%
	SC Recontact	343	35.92%
	Georgia	35	1.90%
	GA Recontact	1	0.10%
	Virginia	500	27.11%
	VA Recontact	236	24.71%
New Respondents	North Carolina	293	31.04%
	South Carolina	302	31.99%
	Florida	301	31.89%
	Other	48	5.08%

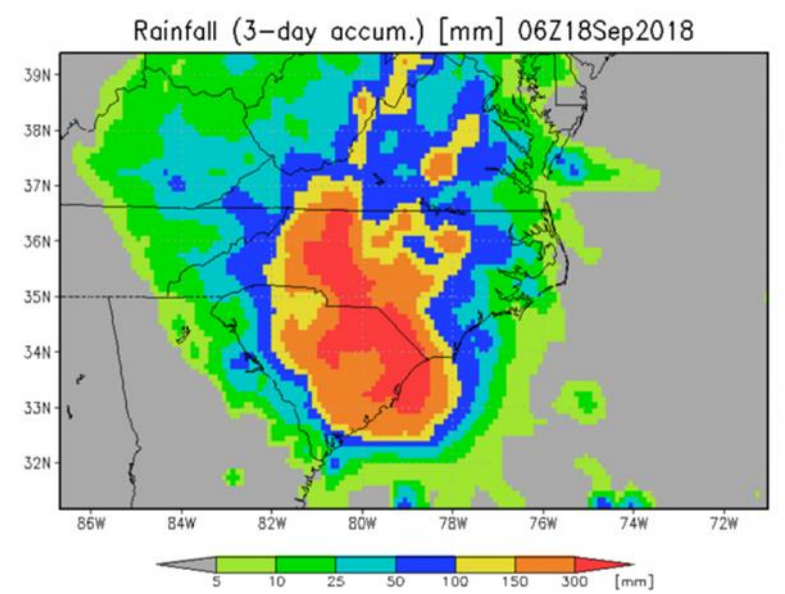

Figure 2. Areas Affected by Hurricane Florence. From "Hurricane Florence Resources - GFMS Flood Forecasts and Inundation Estimates," by NASA Earth Science Disasters Program (https://disasters.nasa.gov/hurricane-florence-2018/hurricane-florence-resources-gfms-flood-forecasts-and-inundation-estimates)

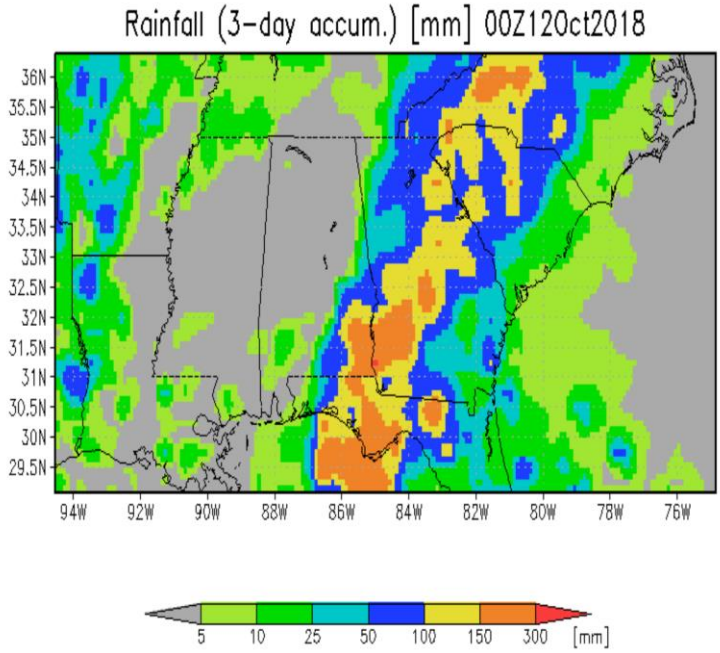

Figure 3. Areas Affected Hurricane Michael. From "NASA's Global Flood Monitoring System Captures Hurricane Michael's Flood and Rain Intensity," by NASA Earth Science Disasters Program (https://disasters.nasa.gov/hurricane-michael-2018/nasas-global-flood-monitoring-system-captures-hurricane-michaels-flood-and)

3. Demographics

The demographic profiles within the geotargeted areas for both the pre and post disaster surveys were closely aligned with the American Community Survey (ACS), an ongoing survey by the U.S. Census Bureau, findings (Table 2). The participants for each sample contained a higher representation of White respondents and a higher level of education than the US Census Bureau's profile. Furthermore, there was a lower representation of higher income respondents.

Table 2. Comparison of Demographics between Pre and Post Florence and ACS

Category	Descriptive	Wave 1 – Pre	Wave 2 - Post	ACS*
Race	White	65%	69%	68%
	Black	24%	23%	25%
	Asian	5%	4%	3%
	Other	6%	5%	4%
Ethnicity	Hispanic or Latino (any race)	8%	6%	8%
	Not Hispanic or Latino	92%	94%	92%
Education	Less than High School	7%	5%	21%
	High School Diploma/ GED	20%	16%	27%
	Some College or Associates	43%	47%	30%
	Bachelors Degree or Above	30%	32%	21%
Income	Less than $25,000	18%	17%	23%
	$25,000 to $34,999	17%	17%	10%
	$35,000 to $49,999	18%	18%	14%
	$50,000 to $74,999	21%	23%	18%
	$75,000 to $99,999	13%	13%	12%
	$100,000 or more	12%	12%	24%

*ACS data matched to geographical locations surveyed

4. Social Vulnerability Index (SoVI)

The Social Vulnerability Index (SoVI) is comprised of fifteen U.S. census variables at the census tract level that reflect socioeconomic and demographic factors that affect the resilience of communities[5]. The SoVI was created for the CDC through the Geospatial Research, Analysis, and Services Program (GRASP) for the use of disaster management by identifying socially vulnerable communities to create effective and efficient aid services. The identification of socially vulnerable areas enables the understanding of substantial affects to disasters, such as, substantial property damage, severe physical

[5] Flanagan, Barry E.; Gregory, Edward W.; Hallisey, Elaine J.; Heitgerd, Janet L.; and Lewis, Brian (2011) "A Social Vulnerability Index for Disaster Management," Journal of Homeland Security and Emergency Management: Vol. 8: Iss. 1, Article 3.

injuries, and emotional distress, which can have devasting economic, health, and social effects on a community[6].

U.S. Census variables are categorized into four domains: socioeconomic status, household composition/disability, minority status language, and housing/transportation. The pre- and post- disaster surveys contained seven of the fifteen SoVI variables (Table 3). For the purposes of this analysis, we used variable endorsement as a method of calculating SoVI, as opposed to the traditional ranking method to classify respondents who were of low, medium, or high social vulnerability. In the pre-disaster survey, there were more variables endorsed than in the post-disaster survey, suggesting more respondents of higher social vulnerability than in the post-disaster survey (Table 4).

Table 3. SoVI Variables

Domain	Variables	Used in pre and post-disaster surveys
Socioeconomic Status	Below Poverty	Yes
	Unemployed	Yes
	Income*	No
	No High School Diploma	Yes
Household Composition/Disability	Age 65 years old or older	No
	Age 17 years old or older	Yes
	Individual with disability	No
	Single-parent household	No
Minority Status/Language	Minority	Yes
	Speak English "less than well"	No
Housing/Transportation	Rent home**	Yes
	Mobile home	No
	Crowding	No
	No Vehicle	Yes
	Group quarters	No

*Questions included in survey; however, alternate response structure does not allow for inclusion in analysis

**Rent Home used as a substitute for "Multi-Unit Structure"

Table 4. SoVI Variable Endorsement

Category	None	Low	Moderate	High
Number of Variables Endorsed	0	1-2	3-4	5-7
Pre-Disaster Survey	27	1,336	718	105
Post-Disaster Survey	44	1,388	630	88

5. Health

Both the pre-disaster and post-disaster surveys asked a series of health-related questions to understand respondents' health coverage, general health, and mental health. Results of health coverage and general health were compared to the Behavioral Risk Factor

[6] CDC's Social Vulnerability Index (SVI). (2018, September). Retrieved from https://svi.cdc.gov/factsheet.html.

Surveillance System (BRFSS) in the geotargeted areas, which gathers data on the state level to identify health-related risk behaviors, use of preventive services, and chronic health conditions of residents[7].

After combining weighted BRFSS data from Georgia, Virginia, Florida, North Carolina, and South Carolina, 86% of residents had healthcare coverage and 14% did not. This finding was similar to survey respondents in both surveys, with 85% having health insurance and 15% without coverage (Table 5). Though, there was more variability when comparing pre-disaster respondents and 2017 BRFSS reported general health as seen in Table 6. The panel reported to be healthier than the BRFSS population surveyed.

Table 5. Health Coverage

INS1: Do you have any kind of health care coverage?	Pre-Disaster (n=2,260)	Post-Disaster (n=1,177)
Insurance through employer	45%	46%
Medicaid	14%	14%
Privately purchased insurance	10%	12%
Medicare	8%	8%
Other	8%	4%
No health insurance	15%	15%

Table 6. Comparison of Pre-Disaster Respondents and 2017 BRFSS Reported General Health

	Georgia		North Carolina		South Carolina		Virginia	
	Pre-Disaster	BRFSS	Pre-Disaster	BRFSS	Pre-Disaster	BRFSS	Pre-Disaster	BRFSS
Poor	1%	5%	1%	5%	2%	6%	4%	4%
Fair	11%	14%	8%	14%	7%	13%	9%	12%
Good	27%	33%	29%	32%	27%	31%	26%	31%
Very Good	39%	30%	40%	31%	37%	31%	41%	33%
Excellent	22%	18%	23%	18%	27%	19%	20%	19%

The mental health of respondents was measured using the Kessler Psychological Distress Scale for pre-disaster and post-disaster re-contacted participants, and the Short Post-Traumatic Stress Disorder Rating Interview (SPRINT), was employed for new post-disaster participants. The Kessler Psychological Distress Scale used a five-point likert-type scale that measured severity of impact of mental health problems through six questions. Depending on how nervous, hopeless, restless/fidgety, depressed, effortless, and worthless a respondent felt, they selected according to the following scale: 0 = not at all, 1 = a little bit, 2 = moderately, 3 = quite a lot, 4 = very much.

The results of each question were combined, mean scores were derived, and compared by coastal and non-coastal divisions, and before and after Hurricane Florence. There were significant differences between coastal and non-coastal respondents, and generally less distress indicated post-disaster. Furthermore, where there were significant differences between pre- and post- Hurricane Florence respondents there were also significant differences between coastal and non-coastal respondents (Table 7).

[7] CDC - About BRFSS. (2014, May). Retrieved from https://www.cdc.gov/brfss/about/index.htm.

Table 7. Mental Health Mean Score Comparisons of Coast and Non-Coastal Respondents

Kessler Psychological Distress Scale		Pre Florence	Post Florence
Nervous	Coastal*	2.68**	2.08**
	Noncoastal*	2.42**	2.02**
Hopeless	Coastal*	1.67**	1.70**
	Noncoastal*	1.48**	1.58**
Restless/ Fidgety	Coastal*	2.41**	1.96
	Noncoastal*	2.16**	1.92
Depression	Coastal	1.65	1.74
	Noncoastal	1.52	1.59
Everything was an effort	Coastal	2.07	2.00
	Noncoastal	1.98	1.99
Worthless	Coastal	1.52	1.59**
	Noncoastal*	1.44	1.53**

* indicates a significant difference between pre- and post- Hurricane Florence respondents (recontacts only)
**indicates a significant difference between coastal and non-coastal respondents

Similar to the Kessler Psychological Distress Scale, the Short Post-Traumatic Stress Disorder Rating Interview (SPRINT) uses a five-point likert-type when asking eight questions focused on assessing the core symptoms of PTSD. According to Norris et al. (2008), PTSD is the most prevalent mental health problem after disasters, and the SPRINT assessment evaluates other significant reactions, such as depression, gives considerable attention to functional impairment, and examining perceived need for help[8]. The results of the SPRINT mean scores were compared to SoVI categories and amount of impact, as seen in Table 7.

Respondents who reported moderate to high impact had a higher SPRINT score (10.57) compared to those who reported low impact to families due to Hurricane Florence or Hurricane Michael (3.23). However, those who were categorized with a moderate to high SoVI (8.41) didn't have as large of a difference from low SoVI respondents (5.43). These results support the effectiveness of the SPRINT assessment capturing a respondents' mental health impact due traumatic events, such as a disaster.

[8] Norris, F. H., Hamblen, J. L., Brown, L. M., & Schinka, J. A. (2008). Validation of the Short Posttraumatic Stress Disorder Rating Interview (expanded version, Sprint-E) as a measure of postdisaster distress and treatment need. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18822839.

Table 7. Short Post-Traumatic Stress Disorder Rating Interview (SPRINT) of Post Hurricane Florence / Hurricane Michael New Respondents Impact to Family and SoVI Mean Comparisons

SPRINT	Moderate to High Impact	Low Impact	Moderate to High SoVI	Low SoVI
…..how much have you been bothered by unwanted memories, or reminders of what happened?	1.07	0.33	0.82	0.59
….. how much effort have you made to avoid thinking or talking about what happened or doing things that remind you of what happened?	0.97	0.35	0.81	0.53
….to what extent have you lost enjoyment in things, kept your distance from people, or found it difficult to experience feelings because of what happened?	0.88	0.18	0.67	0.40
….. how much have you been bothered by poor sleep, poor concentration…..	1.04	0.33	0.82	0.56
….how down or depressed have you been because of what happened?	1.08	0.35	0.85	0.58
….. has your ability to handle other stressful events or situations been harmed?	0.95	0.27	0.72	0.50
….have your reactions interfered with how well you take care of your physical health? ……	0.81	0.24	0.70	0.38
Overall, how distressed or bothered are you about your reactions?	1.05	0.37	0.85	0.57
How much are your reactions interfering with your ability to work or carry out your daily activities….	0.86	0.22	0.66	0.39
How much are your reactions affecting your relationships…	0.84	0.25	0.62	0.42
How concerned are you about your ability to overcome problems you may face without further assistance?	1.02	0.34	0.89	0.51
Total	10.57	3.23	8.41	5.43

Respondents rated the questions based on the following values: 0= not at all; 1= a little bit; 2= moderately; 3= quite a bit; 4= very much

6. Preparedness

Through exploring respondents' preparedness, we examined how distressed respondents felt prior to the storm, and the reasons why post-disaster respondents did not evacuate. When comparing pre-disaster respondents who had experienced a hurricane prior to Hurricane Florence, the most socially vulnerable indicated more nervousness prior to the storm. Respondents with prior experience also felt restless/fidgety across all levels of social vulnerability. Although hopeless feelings had a relatively lower mean score as observed in Figure 4, those who were more socially vulnerable experienced higher levels compared to little to no social vulnerability.

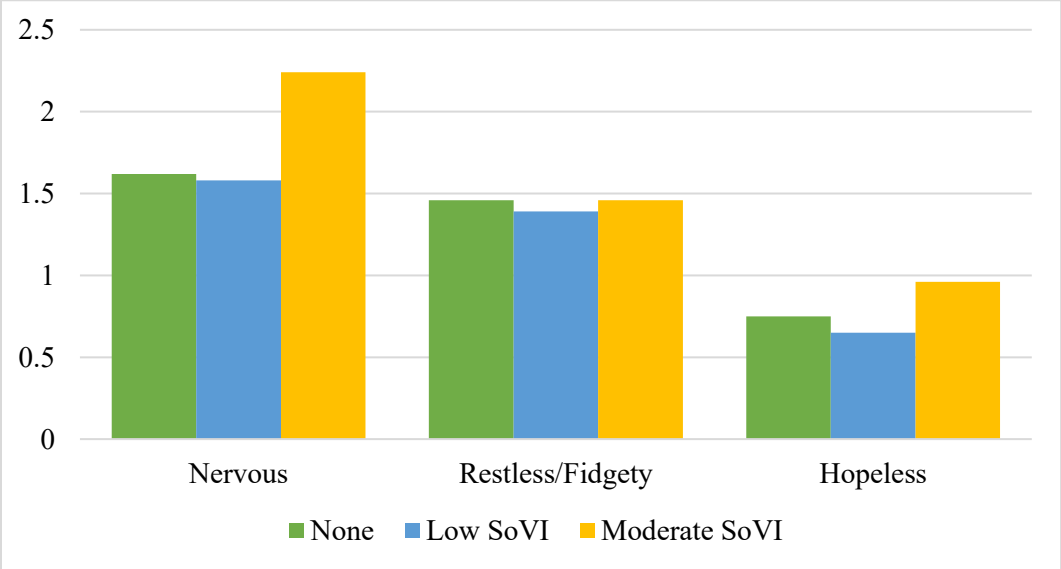

Figure 4: Pre-Hurricane Florence Respondents who have Experienced a Hurricane in the Past: Mean Scores Comparison of Select K6 Distress Items and SoVI Scores*
*Respondents with high SoVI did not report being impacted by a major Hurricane (category 3 or higher) before

Out of the 2,500 participants in the post-disaster survey, 29% of respondents evacuated, and 71% did not evacuate. The primary reason why respondents did not evacuate was due to not being in an evacuation zone with the second reason being they did not think the risk was real. Consequently, a potential challenge is communicating risk to population. Also, those most vulnerable did not evacuate due to resource constraints such as a place to go, means to leave, and expendable funds (Table 8).

Table 8. Reasons Why Post-Disaster Respondents Did Not Evacuate

EV1	None	Low SoVI	Moderate SoVI	High SoVI
Not in Evacuation Zone (self-reported)	71%	61%	51%	39%
No Place to Go	4%	9%	18%	27%
No Means to Leave	8%	8%	16%	23%
No Money to Leave	13%	11%	20%	23%
Shelters Full	0%	1%	2%	4%
Have Pets	4%	19%	14%	13%
Did not think the risk was real	4%	28%	27%	25%
Other	4%	6%	6%	7%

7. Impact

Due to the high number of respondents who chose not to evacuate and the reasons behind their decisions, the extent of the impact and damage was investigated, specifically SoVI score comparisons, flooding, and extent of insurance coverage. Of the post-disaster respondents, 4% had a high SoVI, 30% were moderate, and 66% had a low SoVI score. When SoVI scores were compared to the reported impact to families, as displayed in Figure 5, the more SoVI variables a respondent embodied (i.e. the more socially vulnerable), the more the respondent reported impact.

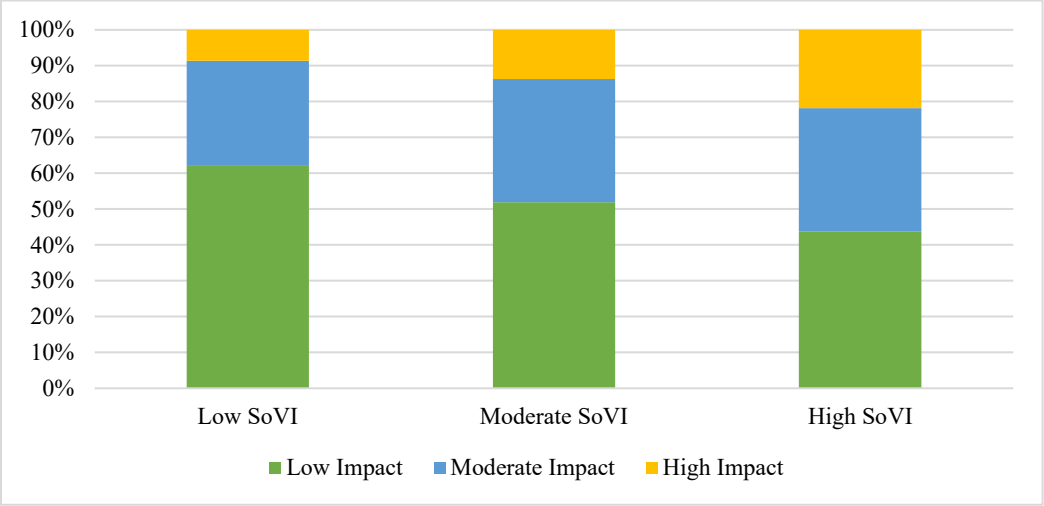

Figure 5: Crosstabulation between SoVI Score and Impact

As seen in Figure 6, this was no exception for the impact flooding had on respondents. Respondents who had a higher SoVI score reported experiencing relatively more severe impact, such as the complete flooding of their home, than lower SoVI scoring respondents. Furthermore, of the high SoVI respondents, only 30% had insurance (Table 9), suggesting the potential for financial hardship as a result of the flooding.

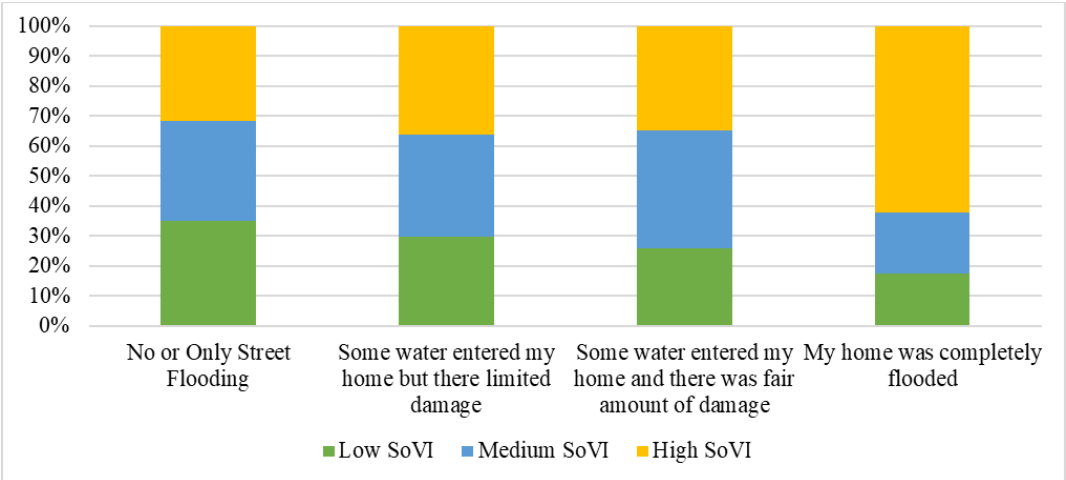

Figure 6: SoVI Scores and Reported Flood Damage

Table 9. SoVI Score and Whether Insurance would Cover Entire Damage Costs

	Insurance Coverage	No Insurance Coverage
None	75%	25%
Low SoVI	79%	21%
Moderate SoVI	53%	47%
High SoVI	30%	70%

Coastal locations within the post-disaster survey who experienced Hurricane Florence reported higher damage costs compared to noncoastal respondents (Table 10). Additionally, across all levels of social vulnerability, 68% reported having insurance, but with the increase in SoVI score, there was a decrease in the amount of insurance coverage that would cover the entirety of damage and mitigate costs associated with the disaster. 70% of those categorized as High SoVI did not have insurance, whereas 47% of Moderate SoVI respondents were without insurance. The significant difference in sufficient insurance coverage is attributable to the limited resources available to socially vulnerable respondents.

Table 10. Post Florence Recontacts Reported Damage

	Coastal (n=102)	Non-coastal (n=290)
$0-$1,000	20%	35%
$1,001-$5,000	35%	30%
$5,001-$10,000	18%	15%
>$10,001	27%	20%

Conclusions

Non-probability mobile panels represent a relatively untapped resource in assessing disaster preparedness and impact. Through the deployment of a pre- and post- survey, change was able to be documented, in addition to, direct impact, specifically respondents' mental health and SoVI. Although the dataset was not weighted, results suggest a fitting representativeness among race/ethnicity when compared to the U.S. Census Bureau's American Community Survey. Moreover, there was a greater amount of reported psychological distress and damage costs among respondents located on the coast. The SoVI scores previously discussed were positively related to the following: disaster impact, psychological distress (pre- and post-disaster), reported flooding, and out-of-pocket expenses (i.e. losses not covered by insurance). The identification of socially vulnerable respondents allowed for a further examination of who was affected and possibly what resources may have been absent or lacking to assist in the reduction of impact and damage costs.

Future Research

The overarching aim of this study was to measure hurricane preparation and impacts, which was made possible through geofencing methods, and executed using a pre-and post-disaster survey, despite dispersion after the event. Although the sample closely represented the

targeted area, in future studies weighting data could reassess the representation of the respondents. Furthermore, including the remaining eight SoVI items to the pre and post-disaster survey would create a more comprehensive understanding of the respondents' social vulnerability. Also, further analysis of disaster preparedness and mental health status has the potential to aid in the identification of needs to better allocate resources for preventive and recovery efforts. For the post-disaster survey, geocoding around aid stations and shelters could increase the probability of reaching people who were significantly impacted by the storm and assess resource availability compared to needs being met by aid agencies to inform planning and preparation prior to the touchdown of the storm. Further studies in this direction will help us gain a deeper understanding of the health, financial, and social impacts of disasters.

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