"Certain Death" from Storm Surge: A Comparative Study of Household Responses to Warnings about Hurricanes Rita and Ike

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ABSTRACT

This study examines the effect of an unusual "certain death" warning message on Galveston, Harris, and Jefferson County, Texas, residents' expectations of storm surge damage and evacuation decisions during Hurricane Ike. The effect of this message was tested by comparing questionnaire data collected after Hurricane Ike to similar data collected 3 yr earlier after Hurricane Rita. If the certain death message had an effect, one would expect nonsignificant differences in perceptions of the two storms' surge threats because the category 2 storm (Ike) had a surge that was more characteristic of a category 5 storm (Rita). However, the ratings of the storm surge threat for Ike were significantly lower than those for Rita in Galveston County—the point of landfall. Moreover, evacuation rates for Ike were consistently lower than those for Rita in all three counties, and there were no statistically significant differences between storms in the correlations of expected storm surge damage with evacuation decisions. In summary, these data fail to show evidence that the dramatic certain death warning increased expectations of surge threat and evacuation decisions. These findings underscore the need for those disseminating weather warnings to better understand how hurricane warnings flow from an initial source through intermediate links to the ultimate receivers as well as how these ultimate receivers receive, heed, interpret, and decide how to act upon those warnings.

1. Introduction

Hurricanes Rita (2005) and Ike (2008) caused extensive damage and many deaths along the coasts of Texas and Louisiana. Rita reached category 5 intensity in the central Gulf of Mexico and then made landfall as a category 3 hurricane between Johnson's Bayou, Louisiana, and Sabine Pass, Texas, at 0740 UTC on Saturday 24 September 2005 (Knabb et al. 2006). During Rita, more than two million people evacuated the coastal areas of Texas and Louisiana. According to Knabb et al. (2006), the storm caused 55 fatalities in Texas, most of which were related to the evacuation rather than storm conditions. Some communities near the Louisiana coast were completely destroyed by storm surge. Rita caused a total estimated damage of about $12.04 billion (U.S. dollars; Knabb et al. 2006).

Hurricane Ike reached category 4 strength in the central Atlantic and then made landfall as a category 2 hurricane along the north end of Galveston Island, Texas, at 0700 UTC on Saturday 13 September 2008 (Berg 2010). During Ike, 112 people were killed, and more than 300 victims were missing in the United States. There was significant damage along the northeast Texas coast that was estimated to be $31.7 billion, making it the third costliest Atlantic hurricane in U.S. history (Huang et al. 2012). Although Rita was a more intense hurricane, Ike had a larger wind field and thus generated an unusually large storm surge for a category 2 hurricane.

The messages from the National Hurricane Center (NHC) contained information on waves, surge, and flooding in their bulletins on both Rita and Ike. In both cases, the bulletins provide information about wind speeds and forward movement speeds first, before coming to possible water hazards. For Rita, the first mention of a water hazard (4–6-ft storm surge) was in the 0200 UTC 21 September bulletin [Landfall (L) = 74 h], which continued through two more bulletins that day. The next mention of water hazard was for 3–4-ft tides in the 1600 UTC 21 September bulletin (L = 60 h). This information changed to a 10–12-ft surge in the 1000 UTC bulletin for 22 September (L = 42 h), was raised to a 15–20-ft surge in the 1300 UTC bulletin

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(L = 39 h), and remained in the bulletins until after landfall at 0400 UTC 24 September.

The first mention of water hazards for Ike was on 10 September in the 0200 UTC bulletin (L = 72 h), which mentioned large swells for Florida. The 1100 (L = 63 h) and 1400 UTC (L = 60 h) bulletins for that day mentioned "above normal tides." From the 1600 UTC bulletin on 10 September (L = 58 h) through the 1900 UTC bulletin on 11 September (L = 31 h), there was reference to "coastal storm surge flooding" and "large and battering waves," with varying levels of surge up to 25 ft. The 2200 UTC bulletin on 11 September (L = 28 h) provided the first mention of a surge that would extend "a greater distance than usual" from the center of the storm because of its unusual size (radius). This information remained in the bulletins until after landfall at 0230 UTC on 13 September.

Mention of Ike's deadly surge potential first appeared in the National Weather Service Houston–Galveston Office (NWS–HGX)'s 11 September 1134 CDT (L = 39 h) local statement, which indicated "persons not heeding evacuation orders in single-family one- or two-story homes will face certain death." This phrase recurred in that day's local statements at 1139, 1320, 1325, 1619, and 2019 CDT. This message was revised to "may face certain death" in local statements at 2317 CDT on 11 September (L = 27 h), as well as 0140, 0500, 0718, 0731, and 0956 CDT on 12 September. The message was revised again to "face the possibility of death" in the 1123 and 1124 CDT local statements (L = 15 h) and was discontinued after that. For example, the 1332 CDT local statement indicated "neighborhoods that are affected by the storm surge. . .and possibly entire coastal communities. . .will be inundated during the period of peak storm tide. Many residences of average construction directly on the coast will be destroyed." It also noted "numerous roads will be swamped. . .some may be washed away by the water. Entire flood prone coastal communities will be cutoff." Subsequent local statements through 0903 CDT on the 13 September continued to emphasize the risk of isolation in areas subject to battering waves.

Morss and Hayden (2010) interviewed 49 Texas coastal residents about the "certain death" warning 5 weeks after Hurricane Ike. They found that 70% of their respondents reported having heard the certain death warning. Of those respondents, 40% expressed positive opinions about it, but 37% had negative reactions; overall, 71% said the statement had no effect on their evacuation decisions. Indeed, Morss and Hayden (2010) reported that 25%–40% of the population of Galveston Island failed to evacuate despite the certain death warning and a mandatory evacuation order.

The Morss and Hayden (2010) study provides preliminary evidence of the effect of the certain death warning, but a deeper understanding of this warning's effect can be gained by examining the warning recipients' perceptions of hurricane threat using the Protective Action Decision Model (PADM), which identifies threat perception as a critical intervening variable between the content of a warning message and a household's protective action decisions (Lindell and Perry 1992, 2004, 2012). Specifically, perceptions of hurricane threat can be categorized in terms of people's expectations about storm characteristics and the personal impacts they will experience (Huang et al. 2012). The storm characteristics that are most relevant to evacuation decisions are a hurricane's location, track, size, intensity, and forward speed (Lindell and Prater 2007). As Huang et al. (2012, p. 285) proposed, "[t]he closer the eye location, the more directly the track points toward an individual's location, the greater the size (radius of hurricane wind) and intensity (maximum sustained wind speed), and the faster the forward speed, the greater will be people's perceptions of threat."

Huang et al. (2012) found that expected storm intensity and landfall proximity were indeed correlated with evacuation decisions in Hurricane Ike. This finding confirmed earlier results from Whitehead et al. (2000), who reported that hurricane intensity was a strongly significant predictor of evacuation in Hurricane Bonnie. It is also consistent with results from Dow and Cutter (2000)'s study of the Hurricane Floyd evacuation, which found that 24% of the respondents in Horry County reported that landfall location was their primary reason to evacuate, in contrast to only 6% of the respondents in other areas of South Carolina. Finally, the Huang et al. (2012) data are consistent with Lindell and Prater (2008)'s finding that expectations of major intensity and nearby landfall were significantly correlated with evacuation decisions in Katrina and Rita and that rapid onset was significantly related to evacuation decisions in Katrina but not Rita.

Huang et al. (2012) also found that the personal impacts people expected from the hurricane were correlated with their evacuation decisions. This result is consistent with findings from Baker (1991)'s review of data from 12 hurricanes and Dow and Cutter (1998)'s finding that evacuation decisions were strongly related to personal risk perception in Hurricane Fran. Similarly, Lindell and Prater (2008) reported that people's expectations of damage to their homes from storm surge, inland flooding, and storm wind, casualties to themselves and their families, job disruption, and service disruption (e.g., loss of electric power) were significantly correlated with evacuation decisions in Katrina and Rita. Finally, expectations of storm wind damage and casualties to self and family were more strongly correlated with evacuation decisions than were expectations of major intensity, nearby landfall, and rapid onset.

In summary, many previous studies have examined people's hurricane evacuation decisions (e.g., Baker 1991; Dash and Gladwin 2007; Dow and Cutter 1998, 2000; Gladwin and Peacock 1997; Huang et al. 2012; Lindell et al. 2005, 2007; Lindell and Prater 2008; Morss and Hayden 2010; Phillips and Morrow 2007; Whitehead et al. 2000; Zhang et al. 2004; Zhang et al. 2007; Gladwin et al. 2001; Whitehead 2005) [see Huang et al. (2013) for a statistical meta-analysis]. However, the warning of certain death from storm surge appears to be unique in the history of U.S. hurricane evacuations. To assess the effect of this warning, we begin by noting that 70% of Morss and Hayden (2010)'s respondents reported having received the certain death warning. Thus, the fact that the respondents were able to recognize a reference to the certain death message means that they had engaged in the PADM's predecision processes of receiving, heeding (i.e., paying attention to), and comprehending the warning (Lindell and Perry 1992, 2004, 2012). Consequently, we focus on the warning's effect on people's perceptions of storm surge threat and their evacuation decisions by formulating two research questions. First, how did the certain death warning affect coastal residents' expectations of storm surge threat? If this message had an effect on risk perceptions, one would expect that expectations of storm surge threat would be at least as high for Ike as for Rita. This is because the category 2 storm (Ike) had a surge that was more characteristic of a category 5 storm (Rita), which had not prompted a certain death warning. A more specific question asks if the certain death message elevated expectations of surge threat relative to storm wind threat, which Lindell and Prater (2008) found to have higher correlations with evacuation than did expectations of storm surge threat.

Second, how did the certain death warning affect households' evacuation decisions? Specifically, if this message had an effect on evacuation decisions, one would expect that the evacuation rates for Ike would be at least as high as those for Rita. In addition, one would expect that there would be stronger correlations of evacuation decisions with expectations of storm surge damage in Ike than in Rita.

2. Methods

In the aftermath of Hurricane Ike, the Texas A&M University Hazard Reduction & Recovery Center conducted a mail survey of coastal residents in the Houston–Galveston area, as well as Jefferson County farther east (see Fig. 1). This questionnaire asked the same questions about factors affecting household evacuation decisions as were asked in Lindell and Prater (2008)'s study of the Hurricane Rita evacuation (Huang et al. 2012; Lin et al. 2014; Siebeneck et al. 2013). Following Dillman (2000)'s *Tailored Design Method*, each household was sent an initial questionnaire, and nonrespondents were sent a reminder postcard and as many as two replacement questionnaires. We terminated this process when nonrespondents had been sent one reminder postcard and three questionnaire packets. The response rates were 39.4% from Ike (Huang et al. 2012) and 35.6% from Rita (Lindell and Prater 2008). These response rates were consistent with the 25%–57% range obtained by other mailed hurricane evacuation surveys—25.7% from the Bret evacuation survey by Prater et al. (2000), 24.6% from the Texas coastal evacuation expectations survey (Lindell et al. 2001), 50.7% from the Lili evacuation survey (Lindell et al. 2005), and 33.5% from the Katrina evacuation survey (Lindell and Prater 2008).

As seen in Table 1, the questionnaire contained three items measuring perceived storm characteristics (e.g., local landfall, major intensity, and rapid onset) and six items measuring expected personal impacts (e.g., storm surge damage, inland flooding damage, storm wind damage, casualties to self and family, job disruption, and service disruption). Each item was rated on a scale from not at all (=1) to almost certain (=5). Evacuation decision was measured as a dichotomous variable (No = 0 and Yes = 1).

3. Results

Regarding expected storm characteristics, Table 2 indicates that respondents had moderate expectations of major intensity [Min = 2.95, Max = 4.02, and Median (Md) = 3.48] and nearby landfall (Min = 3.38, Max = 3.44, and Md = 3.42), but low expectations of rapid onset (Min = 1.61, Max = 2.08, and Md = 1.79). As shown by the effect sizes—computed by the difference between the mean ratings for Rita and Ike as a percentage of the range of the response scale—residents in Galveston (D = 26.8%) and Harris (D = 17.8%) Counties had significantly higher expectations of major intensity from Rita than Ike, but there was no significant difference for Jefferson County (D = 4.5%). There were only slightly higher expectations of nearby landfall for Rita in Galveston County (D = 6.3%) and lower expectations of nearby landfall in Harris (D = −3.8%) and Jefferson (D = −7.8%) Counties. Residents of Galveston (D = 10.3%) and Harris (D = 11.3%) Counties had greater expectations of rapid onset for Rita than Ike, whereas there was a nonsignificantly lower expectation of rapid onset for Rita in Jefferson County (D = −3.8%).

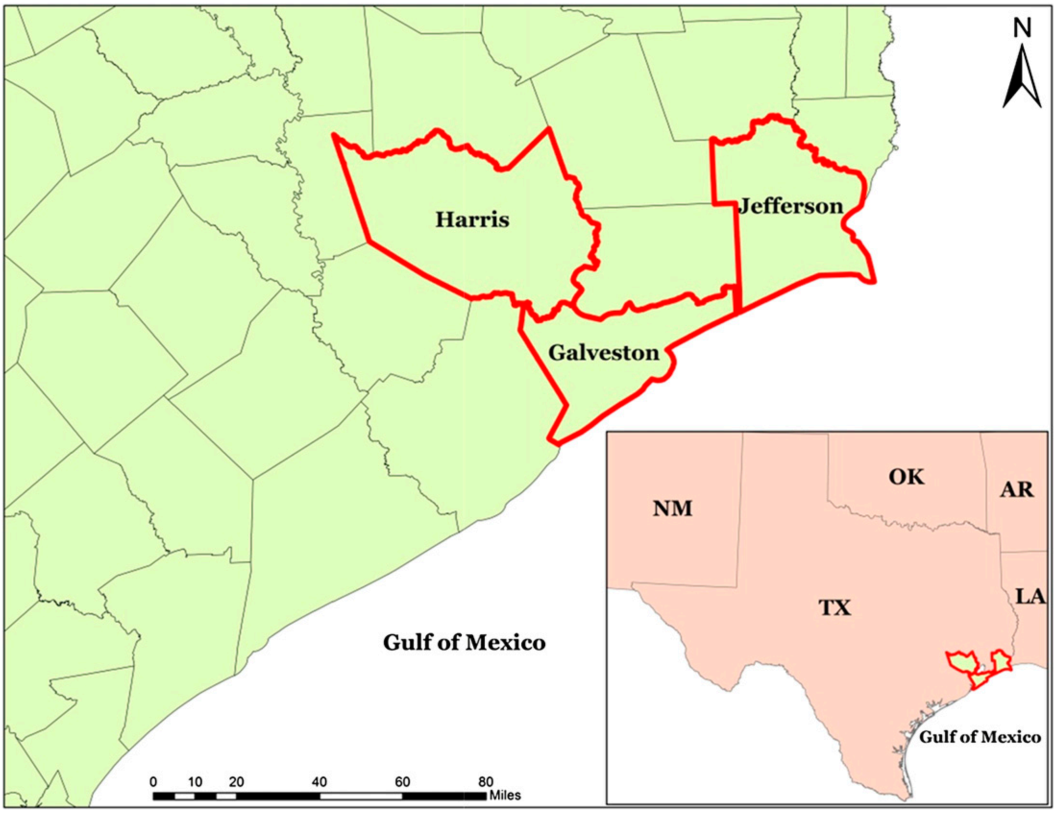

FIG. 1. The three study counties—Harris, Galveston, and Jefferson.

Regarding expected personal impacts, Table 2 shows that—compared to expectations of storm wind damage (Min = 2.58, Max = 3.63, and Md = 3.04)—respondents had relatively low expectations of storm surge damage (Min = 1.56, Max = 3.22, and Md = 2.20) or inland flood damage (Min = 1.96, Max = 2.56, and Md = 2.23) in either storm. As shown by the effect sizes, residents of Galveston County were substantially more concerned about Rita's surge than Ike's surge (D = 26.0%) compared to residents of Harris (D = 5.8%) and Jefferson (D = 4.0%) Counties. That is, despite the certain death warning, Galveston County residents had greater expectations of their homes being inundated by storm surge from Rita than Ike. Respondents in Galveston (D = 22.3%) and Harris (D = 10.3%) Counties also had higher expectations of wind damage from Rita than Ike, but there were no significant differences between storms on this variable in Jefferson County (D = 7.0%). In addition, expectations of casualties (Min = 1.78, Max = 3.29, and Md = 2.57) were substantially higher for Rita than Ike in all three counties (Galveston D = 23.0%, Harris D = 11.8%, and Jefferson D = 9.0%). Finally, expectations of job disruption (Min = 1.89, Max = 3.52, and Md = 3.08) were significantly higher for Rita than Ike in Galveston (D = 11.0%) and Harris (D = 29.3%) Counties but not Jefferson County (D = 3.3%). Expectations of service disruption were very high (Min = 4.39, Max = 4.63, and Md = 4.44) but had nonsignificant differences between storms among the three counties.

TABLE 1. Perceived storm characteristics and expected personal impacts.

As the storm was approaching, how likely did you think it was that. . .
Perceived storm characteristics
(i) the eye of the storm would track through your community?
(ii) the storm would be a major (category 4 or 5) hurricane when it struck?
(iii) the storm would arrive before you could reach safety?
Expected personal impacts
(iv) your home would be inundated by (saltwater) storm surge?
(v) your home would be inundated by (freshwater) inland flooding?
(vi) your home would be severely damaged or destroyed by storm wind?
(vii) you and your family would be injured or killed if you stayed?
(viii) there would be disruption to your job that would prevent you from working?
(ix) there would be disruption to electrical, telephone, and other basic services?

TABLE 2. Results of independent samples t tests between storm characteristics and expected personal impacts.

		Mean ratings			Effect sizes (% of scale)		
Storm threat factors	Hurricane name	Galveston	Harris	Jefferson	Galveston	Harris	Jefferson
Major intensity	Rita	4.02	3.91	3.50			
	Ike	2.95	3.20	3.32	26.8*	17.8*	4.5
Nearby landfall	Rita	3.69**	3.27	3.07**			
	Ike	3.44**	3.42	3.38**	6.3**	−3.8	−7.8**
Rapid onset	Rita	2.02	2.08	1.71			
	Ike	1.61	1.63	1.86	10.3*	11.3*	−3.8
Storm surge	Rita	3.22	1.79	2.37			
	Ike	2.18	1.56	2.21	26.0*	5.8	4.0
Inland flooding	Rita	2.53	2.30	2.56			
	Ike	1.96	1.97	2.16	14.3*	8.3*	10.0*
Storm wind	Rita	3.63	2.99	3.36			
	Ike	2.74	2.58	3.08	22.3*	10.3*	7.0
Casualties	Rita	3.29	2.25	3.13**			
	Ike	2.37	1.78	2.77**	23.0*	11.8*	9.0**
Job disruption	Rita	3.52	3.06	3.08			
	Ike	3.08	1.89	2.95	11.0*	29.3*	3.3
Service disruption	Rita	4.62	4.40	4.41			
	Ike	4.47	4.39	4.63	3.8	0.3	−5.5

* $p < 0.01$. Note that Galveston Rita $N = 134$, Galveston Ike $N = 240$, Harris Rita $N = 126$, Harris Ike $N = 130$, Jefferson Rita $N = 145$, and Jefferson Ike $N = 149$.
** $p < 0.05$.

One limitation of examining the differences in threat ratings between storms is that Rita and Ike had different intensities. One way to control for this confounding variable is to examine the differences between residents' expectations of wind and surge damage from each of the two storms. Table 3 shows that, in all cases, the differences were positive, meaning that people expected wind damage to be more likely than surge damage. Moreover, the differences between expectations of wind and surge damage were quite similar for both storms in all three counties. That is, people did not perceive the surge threat to be any greater—in comparison to the wind threat—for Ike than Rita.

Table 4 indicates that the evacuation rates for Hurricane Ike were consistently lower than those for Hurricane Rita in all three counties. Indeed, the evacuation rate was 30.7% points lower in Ike than in Rita for Galveston County, whereas the differences were 13.0% points lower for Harris County and 19.6% points lower for Jefferson County. That is, despite the certain death warning, people were less likely to evacuate in Ike than Rita. In addition, Fig. 2 shows that the evacuation departure time distributions for Hurricane Ike were later than those for Hurricane Rita in all three counties. The fact that the peak departure day was consistently 1 day later in all three counties is more evidence suggesting that risk area residents perceived Ike to be less threatening than Rita.

Before examining the correlations of different variables with evacuation, it is appropriate to assess the homogeneity of the intercorrelations among variables following Gnanadesikan (1977)'s procedure [see Arlikatti et al. (2007) and Huang et al. (2012) for examples]. This procedure takes the obtained value of each correlation for respondents from the Rita dataset and plots it against the corresponding value of that correlation for respondents from the Ike dataset. For example, one data point is defined by plotting the value of the correlation between expected wind damage and evacuation for the Rita sample on the x axis and the corresponding value of the correlation between expected wind damage and evacuation for the Ike sample on the y axis. Thus, the total number of data points is equal to the number of distinct correlation coefficients in the correlation matrix for each sample—$k(k-1)/2$—where k is the number of variables in the dataset.

TABLE 3. Differences between wind and surge risk perceptions for the three counties.

	Galveston	Harris	Jefferson
Rita	0.41	1.20	0.99
Ike	0.56	1.02	0.87

TABLE 4. Evacuation percentages for the three counties.

	Galveston	Harris	Jefferson
Rita	94.0	46.8	97.9
Ike	63.3	33.8	78.3

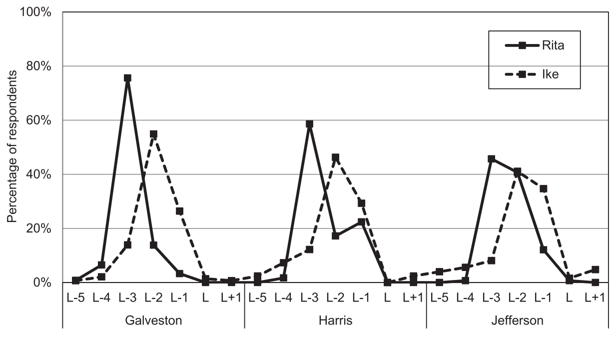

FIG. 2. Evacuation departure time distributions for Hurricanes Rita and Ike.

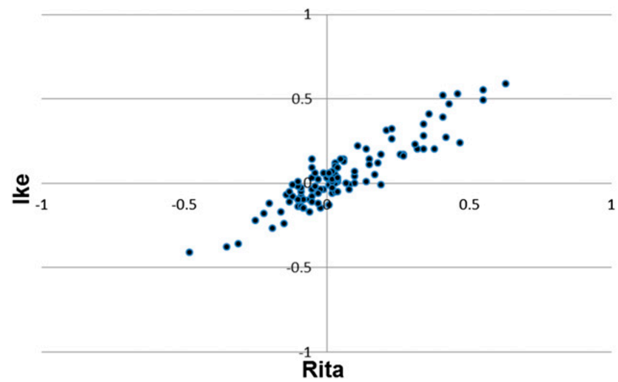

FIG. 3. Cross plot of inter-item correlations for Hurricanes Rita and Ike.

If the cross plot of inter-item correlations for Rita and Ike respondents is approximately linear and has no obvious outliers, then it indicates a similar overall pattern of intercorrelations among the responses to the questionnaire items in the two samples. Consequently, a pooled correlation matrix can be created that ignores the distinction between the two samples in the following analysis. Conversely, if the cross plot of inter-item correlations is widely dispersed or has obvious outliers, the two samples should be analyzed separately to avoid an aggregation error. As Fig. 3 indicates, the cross plot of inter-item correlations for the Rita and Ike respondents is approximately linear and has no obvious outliers, suggesting a similar overall pattern of intercorrelations among the responses to the questionnaire items in the two storms.

Table 5 shows that expected major intensity, nearby landfall, storm surge damage, inland flood damage, storm wind damage, and casualties to self and family generally had statistically significant positive correlations with evacuation. However, the median correlation for casualties (0.37) was higher than for storm surge (0.28), storm wind (0.18), inland flood (0.15), major intensity (0.12), nearby landfall (0.12), service disruption (0.07), job disruption (0.05), or rapid onset (−0.02). There also were higher correlations of storm surge with evacuation from Ike than from Rita in all three counties, but the differences were small and not statistically significant.

Although the correlations of many of the threat perceptions with evacuation differed between hurricanes, few of them were statistically significant. For example, the correlation of nearby landfall was higher for Rita than Ike in Galveston County, whereas the correlations for major intensity and storm wind were higher for Rita than Ike in Harris County. Moreover, the correlation for expected casualties was higher for Ike than Rita in Jefferson County. These variations in the strength and significance of the correlates of evacuation decisions underscore the need for statistical meta-analysis to summarize the effect sizes over multiple studies (Huang et al. 2013).

4. Discussion

This study extends Morss and Hayden (2010)'s finding that 70% of coastal residents received the certain death warning by formulating two research questions about their responses to Hurricanes Rita and Ike. First, how did the certain death warning affect coastal residents' expectations of storm surge threat? Second, how did this warning affect households' evacuation decisions? If the certain death message had an effect on risk perceptions, one would expect that ratings of storm surge threat would be at least as high for Hurricane Ike as for Hurricane Rita because the category 2 storm (Ike) had a surge that was more characteristic of a category 5 storm (Rita)—which had not prompted a certain death warning. Consistent with this expectation, Table 2 shows that Harris and Jefferson County residents had approximately the same expectations of storm surge damage for the two hurricanes but, in both cases, the mean ratings of surge damage were relatively low. Surprisingly, Galveston residents gave significantly *lower* ratings of expected storm surge damage to Ike than to Rita. The difference in ratings of expected storm surge damage was quite large, 26.0% of the response scale, indicating that Galveston residents considered storm surge to be substantially less of a threat in Ike than in Rita.

Although the Harris and Jefferson county residents' expectations of surge damage from Ike were similar to those from Rita, their expectations of wind damage from Ike were also similar to those from Rita. Consequently, calculating the differences between expected damage from wind and surge showed that the relative threat from Ike's surge was roughly the same as the relative threat from Rita's surge in all three counties (see Table 3). Therefore, the results provide no evidence that the dramatic certain

TABLE 5. Correlates of household evacuation decisions.

Variable	County					
	Galveston		Harris		Jefferson	
	Rita	Ike	Rita	Ike	Rita	Ike
Major intensity	0.26*	0.15**	0.29*	0.02	−0.02	0.09
Nearby landfall	0.24*	0.00	0.30*	0.11	0.08	0.12
Rapid onset	−0.02	−0.01	0.07	−0.06	0.06	−0.13
Storm surge	0.29*	0.37*	0.26*	0.35*	0.12	0.17**
Inland flooding	0.12	0.18*	0.30*	0.20**	0.03	0.10
Storm wind	0.26*	0.22*	0.44*	0.14	0.05	0.11
Casualties	0.29*	0.47*	0.51*	0.37*	0.09	0.36*
Job disruption	0.10	0.04	0.28*	0.05	−0.15	−0.11
Service disruption	0.09	0.05	0.21**	0.09	−0.08	−0.02

* $p < 0.01$. Note that Galveston Rita $N = 134$, Galveston Ike $N = 240$, Harris Rita $N = 126$, Harris Ike $N = 130$, Jefferson Rita $N = 145$, and Jefferson Ike $N = 149$.
** $p < 0.05$.

death warning *increased* either the absolute or relative (compared to wind threat) expectations of surge threat in any of the counties—as one would expect from the certain death warning.

Also, if the certain death message had an effect on evacuation decisions, one would expect that the evacuation rates for Ike would be at least as high as those for Rita—especially in Galveston County. However, these data suggest that the evacuation rates for Ike were consistently lower than those for Rita in all three counties (63.3% vs 94.0% in Galveston, 33.8% vs 46.8% in Harris County, and 78.3% vs 97.9% in Jefferson County). In addition, there were nonsignificant differences between Ike and Rita in the correlations of storm surge threat with evacuation decisions for all three counties. Thus, these results show no apparent effect of the certain death warning on increasing households' evacuation decisions—a conclusion that supports Morss and Hayden (2010)'s report that 71% of their respondents said this warning had no effect on their evacuation decisions. It is also consistent with a Hurricane Ike evacuation study that found that most of the households that evacuated did so at least 2 days before landfall, between the time the NHC watches and warnings were issued. Consequently, although a substantial percentage of Galveston households remained in the risk area at the time of the certain death warning, they were the ones that were least inclined to evacuate (Huang et al. 2012).

One limitation of this study is that these data cannot definitively identify the specific cause of the disconnect between the certain death warning message and risk area residents' perceptions of surge threat. It appears that most people received, heeded, and comprehended the certain death message because if they had not they would not be able to report to Morss and Hayden (2010) that they had heard it. Consequently, the problem is likely to lie in later stages of warning message processing. One possibility is that the problem might have been the perceived characteristics of the warning source(s) because most people receive hurricane warnings indirectly rather than from the NHC or local Weather Forecast Office (WFO). However, most of Morss and Hayden (2010)'s respondents reported hearing the warning on TV, which is people's most common source of hurricane information (Lindell et al. 2005). Consequently, a lack of perceived source expertise, trustworthiness, or protection responsibility (Arlikatti et al. 2007) does not seem to be a likely source of the disconnect. A more likely possibility is that the certain death message about surge hazard conflicted with risk area residents' preexisting beliefs about hurricane wind threat. As Table 3 indicates, wind threat was rated higher than surge threat in all three counties for both storms, a result that is consistent with Lindell and Prater (2008)'s finding that storm wind received higher ratings of threat than storm surge for two Louisiana parishes in the Hurricane Katrina evacuations and seven Texas counties in the Hurricane Rita evacuations. Rita was rated higher than Ike on major intensity, storm wind, and casualties—a result that suggests people assume these are related to each other and thus the need to evacuate. Consequently, it was the apparent conflict between the category 2 classification and the warning of certain death from surge that could have caused some of Morss and Hayden (2010)'s respondents to express skepticism about this warning message.

5. Conclusions

Data from evacuation surveys following Rita and Ike show no evidence that the dramatic certain death warning increased risk area residents' expectations of surge damage and evacuation decisions. This comparison of results from two large-scale surveys underscores Morss and Hayden (2010)'s recommendation that agencies disseminating warnings improve their understanding of how people receive, heed, comprehend, and use information about imminent hazards if they want to be effective in influencing people's protective actions. It also indicates that future research needs to make systematic comparisons over multiple storms in order to develop a better scientific understanding of the warning message effects.

The results also support Baker (1991)'s conclusion that people are more likely to evacuate if they think their homes are likely to be damaged by wind or storm surge and thus are more likely to be injured or killed if they remain in the impact area. In summarizing the results from surveys of Hurricanes Lili, Katrina, and Rita, Lindell and Prater (2008, p. 49) found that expectations of wind damage were strongly correlated with households' perceptions of casualties and evacuation decisions, so they encouraged local officials communicate the fact that "hurricane wind speeds might be frightening but are much less dangerous than storm surge and inland flooding—the primary causes of death from hurricanes." The mismatch between coastal residents' risk perceptions and epidemiological data on hurricane casualties makes it crucial for local authorities to incorporate information about the relative impact of these three storm threats into their evacuation advisories and orders.

Future research should attempt to track the messages that come from the National Weather Service, both the NHC and WFOs, through the network of local news media to see which parts of the lengthy bulletins and local statements are highlighted and how they are communicated. This would give a more detailed picture of the ways in which hurricane information flows from the primary initial sources (the NHC and WFOs) through intermediate links (Internet websites, electronic media, print media, and state and local emergency management agencies) to the ultimate receivers (households, businesses, and special facilities) in threatened communities. Such studies would help both the NWS and local media better craft warning messages that are strong enough to penetrate everyday chatter, but avoid potentially counterproductive extremes.

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