RISK AREA ACCURACY AND HURRICANE EVACUATION EXPECTATIONS OF COASTAL RESIDENTS

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ABSTRACT: This study examined the accuracy with which Texas coastal residents were able to locate their residences on hurricane risk area maps provided to them. Overall, only 36% of the respondents correctly identified their risk areas and another 28% were off by one risk area. Risk area accuracy shows minimal correlations with

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respondents' demographic characteristics but is negatively correlated with the respondent's previous hurricane exposure and evacuation experience. Ultimately, risk area accuracy appears to have little significance because it is uncorrelated with evacuation expectations. Instead, the latter were related to respondents' previous hazard experience and expected evacuation context.

Keywords: *risk perception; evacuation expectations; hurricanes*

Hurricanes can devastate hundreds of miles of coastline with high wind, storm surge, rainfall, and tornadoes that cause death, property damage, and economic losses. Casualties, property damage, and economic loss can be reduced if a threatened population is warned in time to evacuate successfully before landfall. During the hurricane season, people depend on the news media and warnings from local officials for information about threatening storms. In particular, risk area residents are most likely to evacuate if they receive information indicating the specific location, time, and intensity of impact (see Lindell & Perry, 2004, for a review of warning research). The most effective method of communicating this information is by using uniformed officers to travel door-to-door urging evacuation and explaining the potentially fatal consequences of remaining in the risk area. However, such warnings are not always feasible in cities with extremely large populations, and a popular alternative method of risk communication is to distribute risk area maps before an emergency arises. In Texas, for example, the Governor's Division of Emergency Management distributes maps intended to help people identify their risk areas, but little is known about how accurately people can identify their map locations.

The principal problem in interpreting these maps is that the risk area boundaries have a complex relationship with the expected depth of surge, elevation of the ground, and distance from the coast so they bear little correspondence to visible terrain features and can be very difficult to interpret in areas with winding rivers and a significant slope in the local topography (see Figure 1). These difficulties compound the usual problems arising from map scale, coding, color, and size. Theoretically, it is important to know if people can read maps correctly and if some demographic segments of the population have more difficulty than others in interpreting maps. In addition, it is important to know whether risk area accuracy has any effect on people's behavior—especially their likelihood of evacuating. There also are practical consequences because those who incorrectly think they are farther away from the coast than they actually are might place themselves at risk by choosing not to evacuate. Conversely, those who inaccurately assess their locations as closer to the coast might evacuate unnecessarily, thus creating congestion

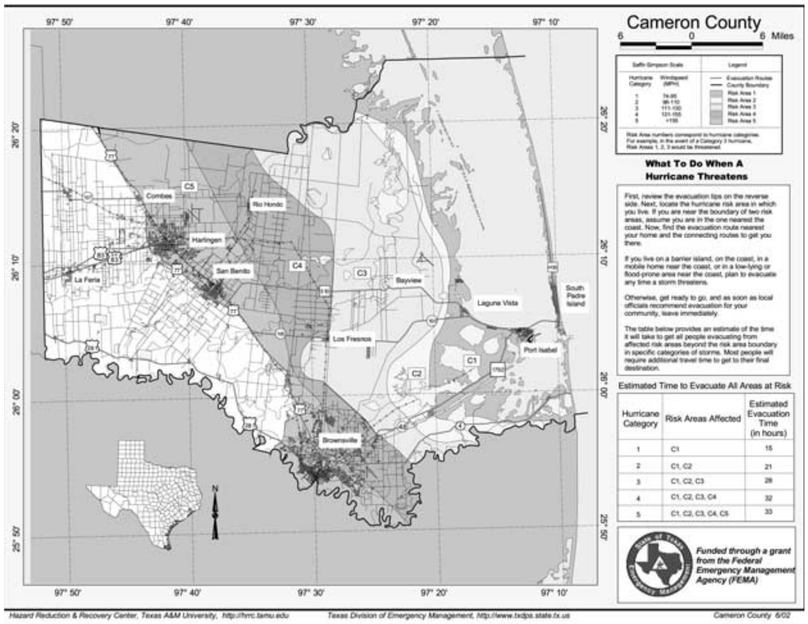

Figure 1. Cameron County Map Showing the Risk Areas Defined by the Five Saffir-Simpson Hurricane Categories

on evacuation routes and threatening the safety of those who actually are at risk.

Research in geography, psychology, and education indicates human cognitive processes interact with cartographic products to produce what Tolman (1949) called cognitive maps, which are the mental images of the environment people derive from perceptual cues. Thus, the properties of a cognitive map are determined by characteristics of each person as well as by characteristics of the map itself (Neisser, 1987; Shepard, 1984). People's previous experiences with maps, their map learning goals, and the task demands required of the viewer during learning all strongly influence people's map images (Kulhavy & Stock, 1996). The features and structural information found in maps aid in the creation of images just as prior knowledge, individual differences, type of map used, and location of features make them easier to remember (Kulhavy, Stock, Werner-Bellman, & Klein, 1993; Paivio, 1986).

Among young children, there is little difference between boys' and girls' mapping abilities, but older boys consistently perform better than girls of the same age in map-drawing and map-reading tasks (Boardman, 1990), and men outperform women in tasks requiring spatial ability (Alington, Leaf, & Monaghan, 1992). Gender differences exist in route knowledge with men having an advantage in both route learning and route recall, but women are better at landmark recall (Schmitz, 1999). Several social and cultural influences on the development and refinement of spatial abilities have been identified as factors contributing to this disparity (Scali, Brownlow, & Hicks, 2000). Indeed several studies on sense of direction and way-finding ability have revealed great differences between individuals (Hirtle & Hudson, 1991; Kozlowski & Bryant, 1977; Montello & Pick, 1993; Weisman, 1981). These findings suggest other demographic variables such as *age*, *length of residence along the coast*, *hazard experience*, and *previous evacuation* behavior might also be relevant to risk area accuracy.

This inference is supported by Zhang, Prater, and Lindell's (2004) study of the Hurricane Bret evacuation, which found some differences in risk area accuracy were associated with income and length of residence along the coast. This study found one third of the respondents misidentified their risk areas, and those who could accurately identify their risk area were more likely to have evacuated during Hurricane Bret than those who underestimated their risk area (i.e., who incorrectly believed that they live farther inland than they actually did). Respondents to this survey might be atypical of coastal residents in general because the respondents had been warned to evacuate from a major hurricane. It is possible this threat led some respondents to seek supplementary sources of information informing them about the risk area in which they were located, and thus, knowledge of their risk area came from information received during the emergency rather than from the risk area map itself. Moreover, Zhang et al. (2004) found evacuation from Hurricane Bret was significantly related to self-reported risk area but not official risk area, risk area accuracy or risk area discrepancy. The first of these findings is consistent with research on evacuation warnings, which has repeatedly confirmed people do not take protective action, even from imminent disasters, unless they believe they are at risk. However, evacuation is also influenced by people's demographic characteristics, hazard experience, and their perceptions of the evacuation context (Baker, 1979, 1991; Drabek, 1986; Fitzpatrick & Mileti, 1991; Gladwin, Gladwin, & Peacock, 2001; Lindell & Perry, 1992, 2004; Mileti, Drabek, & Haas, 1975; Tierney, Lindell, & Perry, 2001).

It also is important to examine the cognitive mechanisms by which risk area residents' beliefs about risk areas might affect evacuation. One of these is that one's risk area is an indicator of a hurricane's likely impacts. Those who live in Risk Area 1, the area closest to the coast, would be likely to personalize the risk (Fitzpatrick & Mileti, 1991; Mileti & Peek, 2000; Mileti & Sorensen, 1988) by anticipating more severe impacts from a hurricane strike. Previous research suggests people think of damage to property in their area, damage to their homes, injury to members of their households, disruption to their jobs, and disruption to basic utilities such as electrical power as the most important impacts of disasters (Lindell & Perry, 2000).

In cases when there has been no disaster and thus no evacuation, it is necessary to assess the behavioral consequences of risk area accuracy by using a proxy for actual behavior. According to Fishbein and Ajzen's (1975) theory of reasoned action, people's volitional behaviors are largely a function of their behavioral intentions. Intentions differ from observed behavior largely as a result of unanticipated impediments to the intended action or unexpected circumstances that facilitate unintended behaviors (Triandis, 1980). In situations where people must predict their future behavior on the basis of minimal information about the circumstances in which it would be carried out, it seems more appropriate to refer to behavioral expectations rather than behavioral intentions because a specific intention has not been made to engage in the behavior. The theory of reasoned action's predictions about the correspondence between intentions and behavior have been supported in research reviewed by Sheppard, Hartwick, and Warshaw (1988) and, more recently, in research on the correspondence between evacuation expectations and later evacuation (Kang, Lindell, & Prater, 2004). Thus, all of the documented antecedents of actual evacuation are expected to affect evacuation expectations as well.

In summary, previous research findings raise questions about risk area residents' risk area accuracy and the relationship of self-reported risk area to hurricane evacuation expectations. This research leads to eight specific hypotheses.

Hypothesis 1: Respondents' self-reported risk area will be significantly correlated with their official risk area (i.e., there will be a significant level of risk area accuracy).

Hypothesis 2: Respondents' demographic characteristics will be significantly correlated with risk area accuracy.

Hypothesis 3: Respondents' hazard experience will be significantly correlated with risk area accuracy.

Hypothesis 4: Respondents' self-reported risk area will be significantly correlated with their expectations of likely hurricane impacts.

Hypothesis 5: Respondents' demographic characteristics will be significantly correlated with their evacuation expectations.

Hypothesis 6: Respondents' hazard experience will be significantly correlated with their evacuation expectations.

Hypothesis 7: Respondents' self-reported risk area will be significantly correlated with their evacuation expectations.

Hypothesis 8: Respondents' expectations of evacuation context will be significantly correlated with their evacuation expectations.

METHOD

This section describes the procedures for preparing hurricane risk area maps, developing questionnaire items, selecting respondents, and distributing questionnaires.

MAPS

The Texas Governor's Division of Emergency Management periodically distributes about 250,000 hurricane risk area maps to the 22 Texas coastal counties. Analysts from the Texas A & M University Hazard Reduction and Recovery Center produced these maps by using a geographical information system to overlay storm-surge inundation and wind-penetration data for each of the five Saffir-Simpson hurricane categories onto topographical maps of the counties. These five hurricane categories define a storm's intensity based on 1-minute average wind speed—Category 1 is 74 to 95 mph (119 to 153 km/hr), Category 2 is 96 to 110 mph (154 to 177 km/hr), Category 3 is 111 to 130 mph (178 to 209 km/hr), Category 4 is 131 to 155 mph (210 to 249 km/hr), and Category 5 is greater than 155 mph (249 km/hr).

The counties vary in size, so the map scales do also. Of the counties, 16 have maps with a scale of 1:316,800 (1 in. = 5 mi.), 2 (Aransas and Harris) have scales of 1:253,440, and 2 (Jasper and Newton) have only a small area displayed at a scale of 1:31,680. Conversely, two large counties (Cameron and Galveston) have maps with scales of 1:380,160, and one (Kenedy) has a scale of 1:443,520 but was not included in the analysis because all mailing addresses in that county were post office boxes and household locations could not be geocoded.

The risk areas corresponding to each of the five Saffir-Simpson hurricane categories were superimposed onto 7.5 inch (19.05 cm) square maps showing county boundaries, principal roads, recommended evacuation routes, and inland water features such as lakes and rivers. Some, but not all, of these features were labeled. Because of variations in elevation, risk areas appear on maps as irregular polygons ranging from more than 3.25 in. (8.23 cm) to less than .05 in. (1.27 cm) in width when measured perpendicular to the coast from a risk area's seaward boundary line to its inland boundary line. For most county maps, .05 in. corresponds to .25 mile on the ground. In some cases, two narrow risk area segments are located adjacent to each other, making it possible for a .10 in. error in reading the map (corresponding to .5 mile in actual distance) to cause respondents to misjudge the location of their homes by two risk areas (e.g., Risk Area 4 instead of Risk Area 2).

RESPONDENTS

During the spring of 2001, the Hazard Reduction and Recovery Center conducted a survey to assess Texas coastal residents' expectations about hurricane evacuation (Lindell et al., 2001). The National Hurricane Center has grouped the Texas coastal counties from the Louisiana state line to the Mexican border into five study areas, so a stratified sampling procedure was designed to yield 500 households from each of the five study areas and 100 households from each of the five risk areas within each study area. The risk area maps were overlaid onto zip code maps to determine the number of households within each risk area that were located in each zip code. A list of randomly sampled names from each zip code was requested from a commercial source to provide the desired number of households within each zip code. Risk area boundaries differ from zip code boundaries, so some households in the sample were in a portion of the zip code that was outside any risk area. These households were classified as Risk Area 6 because they were located inland from the five officially designated risk areas.

PROCEDURE

Following the procedures outlined in Dillman (1978), each household in the sample was sent a black-and-white (grayscale) county risk area map and a two-page questionnaire containing 25 items (additional items not described below addressed evacuation logistics such as expected evacuation preparation times, transportation modes, routes, and destinations; see Kang et al., 2004). Members of the sample who did not return a completed questionnaire within 3 weeks were sent a second packet. This process was repeated until nonrespondents had been sent three packets. A total of 531 households returned usable questionnaires for a gross response rate of 21.2%. Also, 15 households returned duplicate questionnaires with inconsistent responses. Both copies of the questionnaire were deleted, leaving 501 cases in the pool. A total of 231 households were no longer at their original address, undeliverable, or returned incomplete questionnaires. These were removed from the sample without replacement, yielding an adjusted response rate of 22.1%, which is lower than the 31% to 52% range obtained by Mileti and Fitzpatrick (1993) and Lindell and Prater (2000). However, it is comparable to the 25.8% response rate obtained by Zhang et al. (2004). The low response rate might seem to raise questions about the sample's representativeness and, specifically, about the potential for bias in estimates of item means and correlations between variables. Indeed, the survey respondents were predominantly male (63%) homeowners (89%) who were middle-aged (arithmetic mean, M = 52.9 years) and, on an average, had long resided (M = 32.2 years) on the Texas coast. The respondents' households averaged 2.7 persons in size and had an average of 0.6 children under the age of 18. However, the respondents' demographic characteristics are generally similar to the 2000 census data for these counties. Moreover, reports by Curtin, Presser, and Singer (2000); Keeter, Miller, Kohut, Groves, and Presser (2000); and Lindell and Perry (2000) indicate low response rates do not appear to bias central tendency estimates such as means and proportions. Moreover, Lindell and Perry (2000) showed low response rates are very unlikely to affect correlations.

MEASURES

Demographic variables. *Age* is a continuous variable indicating the respondent's self-reported age in years. *Gender* is coded 0 if the respondent is female and 1 if the respondent is male. *Homeownership* is coded with 1 representing homeowner and 0 indicating renter. *Length of coastal residence* is a continuous variable representing the length of time (in years) that the respondent had lived on the Texas coast. *Number in household* is a continuous variable indicating the number of people living in the household and *number of children* is a continuous variable indicating the number of children below 18 years of age living in the household.

Hazard experience. *Hurricane exposure* is coded 1 if a hurricane struck the respondents' area while they lived there and 0 otherwise. *Evacuation experience* is coded 1 if respondents evacuated the area before that hurricane hit and 0 otherwise. *Social sources of information* indicates the extent (from 1 = *not at all* to 5 = *very great extent*) to which their evacuation was influenced by information from local authorities, local media, national media such as the weather channel, posting of a hurricane watch or warning, and the departure of friends, relatives, and neighbors. Responses to these items were added to compute an index ranging from 5 to 25.

Risk area identification. As noted earlier, the official risk area in which the respondents are located was computed by using ArcGIS to geocode the respondent's mailing address and then overlaying these points onto the official risk area boundary file. The street addresses of 359 respondents were successfully geocoded, but the remaining households could not be processed because the address was only a post office box (115 addresses) or had unidentifiable street names (22 addresses). As noted earlier, official risk area ranges from 1 to 6, with 1 to 5 indicating the corresponding risk areas and 6 representing the respondents that were not in any of the five official risk areas. *Self-reported risk area* is the risk area in which the respondents reported they lived. This variable ranges from 0 to 6, with 0 indicating nonresponse, 1 to 5 indicating the corresponding risk areas, and 6 designating respondents who did not think they were in any of the five official risk areas. *Risk area accuracy* is coded 1 if a respondent reported risk area matched his or her official risk area and 0 otherwise. *Risk area discrepancy* was computed by subtracting the self-reported risk area from the official risk area. This variable ranges from –5 to +5, with positive values identifying respondents who incorrectly think they live in a more dangerous area (closer to the coast), 0 identifying respondents reporting the correct risk area, and negative values identifying respondents incorrectly reporting a less dangerous area.

Evacuation context. Expected deterrents are five factors found to affect people's evacuation decisions. Respondents reported whether they thought the possibility of being in a major accident, being caught in severe winds or flooding, losing income while away from work, bearing out-of-pocket expenses while away from home, or having their homes looted would affect their decision to evacuate. Responses to these items were added to compute an index ranging from 5 to 25. *Likely impacts* rated by respondents included the extent to which they expected a hurricane to cause major property damage in their area, major damage to their homes, injuries to household members, disruption of their jobs, or disruption to basic utilities such as electrical, telephone, and other basic services in the coming hurricane season. Responses to these five items were added to compute an index of ranging from 5 to 25. Respondents reported their warning confidence in terms of the likelihood that a hurricane would actually strike their neighborhood if they were warned and whether they expected to receive a warning in time to evacuate. Responses to these two items were added to compute an index ranging from 2 to 10.

Evacuation expectations. *Evacuation category* is the lowest category of storm from which a respondent expected to evacuate. The variable ranges from 1 to 5 corresponding to the five Saffir-Simpson storm categories.

Evacuation shadow indicates whether respondents expected to evacuate if an evacuation advisory was issued for the risk area adjacent (either laterally or seaward) to theirs (coded as 1) or not (coded as 0).

RESULTS

Table 1 shows the mean (*M*), standard deviation (*SD*), and intercorrelations (r) for each variable. Hypothesis 1 was supported by a statistically significant correlation between official risk area and self-reported risk area (r = .49). Although this correlation between official risk area and self-reported risk area provides a useful summary index, a confusion matrix is needed to test the hypothesis more specifically. Table 2 crosstabulates each respondent's official risk area (row) against his or her self-reported risk area (column). If the respondents were perfectly accurate, all of those in each official risk area would list it as their reported risk area so the diagonal elements of the matrix would be 100% and the off-diagonal elements would be 0s. In fact, only 129 out of the 359 (35.93%) respondents correctly identified their risk areas. Another 103 (28.69%) misjudged their locations by one risk area and 102 (28.41%) gave answers that were incorrect by two or more risk areas. Risk Areas 2 and 4 had noticeably lower levels of risk area accuracy (29.17% and 20%, respectively) than did Risk Areas 1, 3, and 5 (43.75%, 39.60%, and 40.00%, respectively).

Contrary to Hypothesis 2, the results showed none of the demographic characteristics was significantly correlated with risk area accuracy. By contrast, Hypothesis 3 was partially supported. Risk area accuracy had a significant correlation with hurricane exposure, but the sign was negative rather than positive as one might expect (r = –.13). There was no significant correlation of risk area accuracy with evacuation experience or social sources of information. Risk area discrepancy had a significant negative correlation with social sources of information (r = –.11) but no significant correlation with hurricane exposure or evacuation experience. Contrary to Hypothesis 4, there was no correlation between self-reported risk area and likely hurricane impacts.

There was slight support for Hypothesis 5. Age and length of coastal residence were significantly correlated with evacuation expectations, but these were the only two of the twelve correlations that were statistically significant. However, support was much stronger for Hypothesis 6 because four of the six correlations of hazard experience were significantly correlated with evacuation expectations. The category of storm at which the respondents expected

(text continues on p. 239)

TABLE 1
Variable Means, Standard Deviations, and Intercorrelations

Variables	M	SD	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Demographics											
1. Age	52.94	14.97									
2. Gender	0.63	0.48	0.01								
3. Homeownership	0.89	0.32	0.18	0.15							
4. Length of residence	32.22	19.87	0.37	–0.08	0.17						
5. Number in household	2.66	1.35	–0.45	0.13	0.00	–0.14					
6. Number of children	0.62	0.98	–0.51	0.09	–0.04	–0.18	0.82				
Hazard experience											
7. Hurricane exposure	0.77	0.42	0.08	–0.10	–0.07	0.31	–0.05	–0.11			
8. Evacuation experience	0.46	0.50	0.03	–0.09	–0.03	0.12	–0.04	–0.04	0.50		
9. Social sources of information	8.10	9.33	–0.08	–0.08	–0.06	0.09	0.03	0.02	0.31	0.57	
Risk area identification											
10. Official risk area	3.12	1.61	–0.04	0.08	0.12	0.16	0.14	0.08	–0.12	–0.21	–0.17
11. Self-reported risk area	2.93	1.79	–0.07	0.01	0.07	0.06	0.08	0.02	–0.07	–0.11	–0.05
12. Risk area accuracy	0.36	0.48	–0.02	0.09	0.04	–0.06	0.03	0.02	–0.13	–0.03	–0.06
13. Risk area discrepancy	0.19	1.73	0.03	0.06	0.04	0.08	0.04	0.06	–0.04	–0.09	–0.11
Evacuation context											
14. Expected deterrents	11.12	5.15	–0.22	–0.02	–0.11	–0.11	0.24	0.22	0.07	–0.10	0.05
15. Likely impacts	14.78	5.76	–0.12	–0.02	–0.08	–0.02	0.20	0.17	0.08	–0.20	–0.06
16. Warning confidence	25.90	10.50	–0.17	–0.02	–0.10	–0.06	0.23	0.20	0.08	–0.16	–0.01
Evacuation expectations											
17. Evacuation category	3.34	3.04	0.13	–0.03	0.02	0.15	–0.01	–0.04	0.04	–0.23	–0.22
18. Evacuation shadow	0.32	0.47	0.03	0.08	0.09	0.03	–0.01	0.01	0.03	0.19	0.14

Variable	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
Demographics								
1. Age								
2. Gender								
3. Homeownership								
4. Length of residence								
5. Number in household								
6. Number of children								
Hazard experience								
7. Hurricane exposure								
8. Evacuation experience								
9. Social sources of information								
Risk area identification								
10. Official risk area								
11. Self-reported risk area	0.49							
12. Risk area accuracy	–0.05	0.03						
13. Risk area discrepancy	0.43	–0.58	–0.08					
Evacuation context								
14. Expected deterrents	0.02	0.01	–0.02	0.01				
15. Likely impacts	0.05	0.00	–0.02	0.05	0.85			
16. Warning confidence	0.04	0.00	–0.02	0.03	0.96	0.97		
Evacuation expectations								
17. Evacuation category	0.06	–0.01	0.00	0.07	–0.06	0.46	0.22	
18. Evacuation shadow	–0.05	–0.05	0.03	0.00	–0.10	–0.06	–0.08	–0.10

NOTE: The smallest value that is significant at $p < .05$ (two-tailed) is $r_{ij} = 0.11$.

TABLE 2
Risk Area Confusion Matrix

	Reported Risk Area														
	1		*2*		*3*		*4*		*5*		*6*		*No Answer*		
Official Risk Area	n	%	n	%	n	%	n	%	n	%	n	%	n	%	*Total*
1	35	43.75	11	13.75	20	25.00	2	2.50	3	3.75	4	5.00	5	6.25	80
2	14	29.17	14	29.17	7	14.58	2	4.17	2	4.17	3	6.25	6	12.50	48
3	18	17.82	18	17.82	40	39.60	3	2.97	6	5.94	7	6.93	9	8.91	101
4	3	6.00	3	6.00	17	34.00	10	20.00	8	16.00	7	14.00	2	4.00	50
5	1	2.50	2	5.00	8	20.00	6	15.00	16	40.00	6	15.00	1	2.50	40
6	1	2.50	4	10.00	3	7.50	3	7.50	13	32.50	14	35.00	2	5.00	40
Total	72		52		95		26		48		41		25		359

to evacuate was significantly correlated with evacuation experience ($r = -.23$) and social sources of information ($r = -.22$) but not hurricane exposure. Similarly, *evacuation shadow* was significantly correlated with evacuation experience ($r = .19$) and social sources of information ($r = .14$) but not hurricane exposure.

Hypothesis 7 was totally unsupported. None of the risk area identification variables had significant correlations with either of the two evacuation expectations variables. However, Hypothesis 8 received substantial support with two of the evacuation context variables having significant correlations with expected *evacuation category* (likely impacts, $r = .46$; warning confidence, $r = .22$), but none of the evacuation context variables was correlated significantly with *evacuation shadow*.

The significantly lower level of risk area accuracy in this study, compared to that reported by Zhang et al. (2004), raises questions about differences in the two studies. One possible answer lies in the fact that Zhang and his colleagues reported data collected from the area threatened by Hurricane Bret. These are four of the southernmost counties—Cameron, Willacy, Kleberg, and Nueces (as noted earlier, Kenedy County was not analyzed because all addresses were post office boxes that could not be geocoded). These comprise all of the Valley study area and part of the Coastal Bend study area. Table 3, which shows risk area accuracy by study area, indicates significant differences in risk area accuracy among all five study areas with the average accuracy for the Valley and Coastal Bend study areas (40.3%) being higher than the average for the Matagorda, Houston and Galveston, and Lake Sabine study areas (33.0%). However, even the Valley and Coastal Bend study areas had lower levels of risk area accuracy in this study than in the previous one.

DISCUSSION

An evaluation of coastal residents' risk area accuracy shows only 36% could correctly identify the risk areas in which their homes were located. This is even lower than the level reported by Zhang et al. (2004) and raises questions about why it occurred. One possibility is the grayscale maps sent with the questionnaires provided insufficient information to distinguish among the risk areas. However, this explanation is undercut by other research indicating that color often has little effect on participants' recall of map information (Patton & Slocum, 1985; Potash, Farrell, & Jeffrey, 1978; Shurleff & Geiselman, 1986) and, in any event, the Zhang et al. (2004) maps were also grayscale.

TABLE 3
Risk Area Accuracy by Study Area

Study Area	*% Correct*	*% Off by 1*	*% Off by ≥ 2*	*% No Answer*	n
Sabine study area	44.44	29.17	25.00	1.39	72
Houston and Galveston study area	28.26	30.43	29.35	11.96	92
Matagorda study area	25.49	25.49	41.18	7.84	51
Corpus Christi study area	37.63	31.18	22.58	8.60	93
Valley study area	45.10	23.53	29.41	1.96	51

NOTE: Total number of respondents = 359. 25 (6.96%) did not answer.

Another explanation is suggested by the finding that what is remembered from a map depends on the viewer's intent (Kulhavy & Stock, 1996). Filling out a questionnaire and identifying their household's location on a map in a nonemergency situation might not have been sufficiently motivating and thus led to lower levels of accuracy. If this were the case, however, one would expect those with hurricane experience to be more accurate. In fact, the opposite was the case—those with hurricane experience were less accurate.

A third explanation stems from the disparities among risk area boundaries, political boundaries (e.g., city limits), artificial features (e.g., roads), and natural features (e.g., rivers), which might make it difficult for people to accurately locate their households on the maps. As noted earlier, risk areas are irregularly shaped polygons that are as narrow as .05 in. (1.27 cm) in width when measured perpendicular to the coast from a risk area's seaward boundary line to its inland boundary line. This can make it very difficult to judge a house's location, particularly when there might be three or more risk areas in a single community. This explanation is supported by the finding that people encode two types of information from a map, namely feature and structural information. Feature information consists of color, form, size, and individual point markers or locations on a map. Structural information refers to the spatial framework within which the map features are embedded, such as the geometric and metric relationships between the features and the clear definitions of borders and paths that can serve as reference points to the viewer (Johnson, Verdi, Kealy, Stock, & Haygood, 1995). With the help of these cues, people are able to form accurate images and process them as required (Kulhavy et al., 1993). The low level of risk area accuracy in the present study suggests respondents did not form such images either because the map scales were too small or because there was an inadequate number of feature markers on the maps. Unfortunately, there are practical constraints to recommending an increase in the amount of map detail because an excessive detail would produce so much clutter (densely spaced features and legends) on a small map that accuracy would suffer in this case also. Clutter could be avoided by increasing the size of the maps, but this would significantly increase the cost of map production. The State of Texas produces almost 250,000 brochures containing these maps, so increasing their size (e.g., to 11 in. by 11 in.) would incur a substantial cost.

A fourth explanation arises from the distinction between message comprehension and yielding (McGuire, 1985). Specifically, respondents might have comprehended the information in the maps but not yielded to it because of strong prior beliefs derived from other sources—such as local authorities, local news media, or peers—that provided inaccurate information that they considered to be more credible. This explanation seems implausible because it seems unlikely that local authorities or local news media would provide incorrect information, and the cover letter indicated the study was being conducted for a state agency. Regardless of what caused the low level of risk area accuracy, the data in Table 1 suggest these risk area errors have minimal implications for future evacuations because the risk area identification variables (official risk area, self-reported risk area, risk area accuracy, and risk area discrepancy) all had nonsignificant correlations with the evacuation expectations variables (*evacuation category* and *evacuation shadow*). This is particularly noteworthy because Kang et al. (2004) found evacuation expectations were significantly related to later evacuation in Hurricane Lili.

It is remarkable that demographic characteristics were not significantly related to risk area accuracy because this finding appears to contradict research indicating the correspondence between a map and the image it produces is determined by characteristics of the person who reads it as well as by characteristics of the map itself (Kulhavy et al., 1993; Neisser, 1987; Shepard, 1984). It is particularly surprising that a gender effect was not found, but the absence of one replicates the findings of Zhang et al. (2004). However, as noted earlier, Zhang et al. found income (but not education) and length of residence on the coast were correlated with risk area accuracy. The effect of income is difficult to explain but Zhang et al. interpreted length of residence as measuring familiarity with the geography of the region. This correlation was not replicated in the present study, so further research is needed to determine if there are reliable effects of demographic variables on risk area accuracy.

The correlations of hazard experience variables with evacuation expectations are consistent with previous research. This study's finding that self-reported risk area was uncorrelated with evacuation expectations is consistent with the finding that self-reported risk area was uncorrelated with evacuation from Hurricane Bret (Zhang et al., 2004). Similarly, the present finding that coastal tenure was negatively related to expected evacuation is consistent with the findings of Zhang et al. regarding these variables. Moreover, the nonsignificant correlation of hurricane experience supports Baker's (1991) conclusion that the effect of this variable depends on how it is measured and, more importantly, how risk area residents interpret that experience (Lindell & Perry, 2004). The negative correlation of evacuation experience with likely impacts is consistent with research suggesting risk area residents are affected by gambler's fallacy (Slovic, Kunreuther, & White, 1974), which causes them to conclude erroneously that the recent occurrence of a rare event (i.e., hurricane impact) decreases its probability. Moreover, the significant correlations of evacuation experience and social sources of information with *evacuation category* and *evacuation shadow* are also consistent with previous research because those who have evacuated from previous hurricanes are more likely to have done so in response to contacts with social sources of information and are also more likely to evacuate in response to future hurricanes (Baker, 1991).

The finding that older respondents expected to evacuate only for more intense storms warrants attention because it helps resolve uncertainty about whether higher death rates among older citizens are best explained using either cognitive or social mechanisms (Perry & Lindell, 1997). The positive correlation of age with *evacuation category* in Table 1 means older residents expect to evacuate only for more intense storms, whereas the nonsignificant negative correlation of age with social sources of information indicates they were somewhat less likely to rely on social networks in previous hurricanes. The present results do not indicate whether these citizens were more socially isolated or they were just as integrated in their communities but paid less attention to the social sources of information. Moreover, there is a lower expectation of hurricane impacts, which would seem to inhibit evacuation but lower warning confidence and expectations of fewer impediments, both of which would seem to promote evacuation. These conflicting findings about evacuation decisions by older residents indicate a need for further research.

The strong positive correlation between likely impacts and evacuation expectations supports the importance of risk personalization in determining people's propensity to evacuate (Fitzpatrick & Mileti, 1991; Mileti & Peek, 2000; Mileti & Sorensen, 1988). In fact, this result extends previous findings by showing risk personalization can take place before a disaster strikes and is strongly correlated with a behavior (evacuation expectations) that is equivalent to but distinct from actual evacuation. However, the results are problematic for local emergency managers because Table 1 shows the evacuation context variables have only four possible causal antecedents that were measured in this study. *Evacuation experience*, *age*, *number in household*, and *number of children in household* all are temporally prior to and reliably correlated with the three evacuation context variables, but none of the four potential causal antecedents is a variable emergency managers can influence. There undoubtedly are other variables that cause expected impacts and warning confidence but they must be addressed in future research because none of these other variables was measured here.

The similarities between this study's findings and those of previous research are noteworthy because the dependent variable in this study is an expectation rather than an actual behavior. The difference between these two dependent variables is significant because actual evacuation is affected by a variety of social phenomena such as information seeking from authorities, the news media, and peers (Drabek, 1986; Tierney et al., 2001). In addition, actual evacuations are constrained by the separation of family members and the preference for evacuating as a family unit. Thus, the similarity of the findings for evacuation expectations and actual evacuations suggests risk area residents' evacuation decisions have dispositional as well as situational components—that is, the information people receive during an emergency modifies a preexisting readiness to evacuate (or stay) rather than acting as the sole determinant of evacuation decisions. However, it is unclear which stages of the evacuation decision process are affected by previous evacuation experience—risk identification, risk assessment, protective action search, protective action assessment, information needs assessment, or communication action assessment (Lindell & Perry, 2004). Further research is needed to resolve this ambiguity.

Despite the many instances of consistency with previous research, there were some unexpected findings. Specifically, those respondents with evacuation experience had lower warning confidence and expected less severe impacts, although they expected to evacuate at lower storm categories. It is understandable that those with lower warning confidence would expect to evacuate for weaker hurricanes because these storms can change course or intensify just before landfall, and these respondents might be reacting to the inherent uncertainty in hurricane warnings. In addition, those who owned their homes and those who had longer tenure on the coast expected fewer deterrents to evacuation. Moreover, those with greater tenure expected to evacuate only in stronger hurricanes. One might assume these findings can be explained by greater familiarity with the geography of their communities, but this explanation also implies evacuation deterrents would have a significant correlation with *evacuation category*, which was not the case. Even more significant was the finding that those who had more household members (usually children) expected more evacuation deterrents and greater hurricane impacts. However, these did not translate into expectations for evacuation at lower hurricane categories. Those with larger households also had greater warning confidence but there is no apparent theoretical basis for this finding.

As noted earlier, the generalizability of this study's findings to the rest of the coastal population does appear to be limited by the low response rate (22.1%), which was further reduced (15.8%) due to limitations in geocoding capabilities. However, such concerns should be allayed by empirical evidence that low response rates do not seem to bias estimates of central tendency (in this case, the proportions of respondents correctly identifying their risk areas), and there are statistical arguments why low response rates are unlikely to bias estimates of the correlations used to test the hypotheses. Thus, despite its low response rate, the study does have very significant implications for local emergency managers on the Texas coast. First, these data—together with those of Zhang et al. (2004)—suggest between one third and two thirds of those in the risk area misinterpret their location on risk area maps. These results indicate local emergency managers should not assume distribution of these maps will inform the population of their risk areas and, in turn, lead them to make accurate decisions about when to evacuate. Instead, one of three actions should be taken. First, one can print larger maps so larger scales can be used and landmarks can be labeled extensively without producing a cluttered presentation. The additional cost of larger maps could be offset by commercial sponsors such as home improvement centers that could be charged to place their logos on the maps.

Second, one could redefine the risk areas so their boundaries follow easily recognized landmarks such as roads and rivers rather than topographical contours. This would require analysts to extend risk area boundaries inland from their current locations, but boundary redefinition should not prove to be a problem. If the boundaries need to be moved a significant distance because there are few roads in the area, this will be because the area is sparsely populated and so few people are likely to be affected. Conversely, if a geographical area is so densely populated that many people would be affected, then there are almost certain to be many roads to which the new risk area boundaries can be moved.

Third, one can reduce the number of risk areas by identifying the ones that are least accurately identified and combining them with the adjacent risk areas with which they are most frequently confused. Inspection of Table 2 indicates residents of Risk Area 2 had very low accuracy and most often confused it with Risk Area 1, so these two might be combined. Similarly, residents of Risk Area 4 had very low accuracy and most often confused it with Risk Area 3, and these two might be combined. An alternative method of reducing the number of zones is to combine Risk Areas 1 and 3 into one risk area and Risk Areas 4 and 5 in another, which takes advantage of the fact that few people misclassified their risk areas by two or more categories.

In summary, this research underscores the need for local emergency managers to use multiple forms of communication to inform risk area residents about hurricane hazard. Maps can be used as a supplement to risk awareness programs but the present research indicates a need to identify each household's location on the map, explain the expected effects of wind and surge, and the potential for death, injury, and property damage at those locations.

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