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PREDICTING RESPONSE TO HURRICANE WARNINGS: A REANALYSIS OF DATA FROM FOUR STUDIES

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INTRODUCTION

With the rapid buildup of population in coastal areas, concerns are growing that hurricane disasters involving thousands of casualties may lie in the nation's not-so-distant future (American Meteorological Society, 1976; Baker, 1978). The principal means of averting such losses is the process of warning and evacuation, the adjustment which is primarily responsible for the trend of decreasing hurricane deaths since the turn of the century (National Oceanic and Atmospheric Administration, 1972). General consensus exists that major improvements in forecasting hurricane landfall locations is unlikely in the foreseeable future, however. For that reason, one outgrowth of the National Science Foundation-supported Assessment of Research on Natural Hazards project was a recommendation that research into issues which could improve warning response be given increased priority (Brinkmann, 1975). As a member of the team which formulated that proposition, I feel that a more critical examination of the role of social scientific research into the hurricane warning-response system is merited.

Studies dealing with hurricane evacuation date back to at least 1953 (Rayner), but four post-hurricane sample surveys provide the basis of most of what is known (or believed) about human response to hurricane warnings (Moore et al., 1963; Wilkinson and Ross, 1970; Baker et al., 1976; Windham et al., 1977) [1].

The four sample survey studies mentioned above will be reviewed, and their analyses will be extended with respect to one dependent variable: whether or not the survey respondent evacuated his or her home in response to the hurricane warning. The goal of the review is to identify useful variables which predict evacuation behavior. Three criteria will be employed for selection of useful predictors: (1) statistical significance, (2) strength of association, and (3) replicability. Initially a χ^2-test of independence is performed for each contingency table. If a relationship between evacuation and the predictor is detected at the .05 level of significance, a measure of the strength of the association (Goodman and Kruskal's τ_b) is computed. Finally, consistency of the findings across studies is assessed. All statistics reported for the Moore et al., Wilkinson and Ross, and Windham et al. studies were computed by the author from raw data appearing in the original survey reports. Most of the statistics for the Baker et al. study were computed from data not appearing in the original report.

THE STUDIES AND THEIR STORMS

Specific characteristics of a given storm affect the warning process and, presumably, the response to warnings. For example, storm intensity, storm behavior prior to landfall, time of landfall, and speed of onset of a hurricane might interact with the predictor variables to affect the evacuation decision. To explicate as many of the relevant warning response factors as feasible, the three hurricanes are discussed below.

Carla [2]

The first major investigation of hurricane warning response occured a few weeks after hurricane Carla in 1961. Carla appeared as a tropical depression in the Caribbean on Monday, September 4, eventually moved through the Yucatan channel into the Gulf of Mexico, and by Friday (September 8) was labeled a "large and dangerous" hurricane. Forecast landfall location was revised several times westward; on Friday, Carla was expected to hit in the area of the "mouth of the Mississippi." Saturday the storm was forecast to make landfall near the Sabine Pass, and evacuation was advised from low-lying areas of Louisiana and the upper Texas coastlines. At that point, however, Carla became almost stationary still more than 200 miles offshore, alternately threatening Galveston and Corpus Christi. Finally, during late afternoon on Monday, September 11, the hurricane made landfall about 60 miles northeast of Corpus Christi. As predicted, it was a large and severe hurricane, with hurricane-force sustained winds extending over an area more than 100 miles wide. Peak gusts were estimated at 175 m.p.h., and storm surge was over 16 feet; wave uprush established an inside high water mark of 22 feet.

Number of evacuees might have been as high as half a million, or more than 60% of the population of the warning area. "Only" 45 deaths were reported, and the evacuation was regarded as successful, compared to what some observers expected (almost 600 were killed in southwestern Louisiana by Audrey just four years before).

Interviews were conducted in more than 1,500 households ranging from Cameron Parish, Louisiana to Calhoun County, Texas (the area of maximum impact). Data was collected a few weeks following the hurricane (Moore et al., 1963).

Camille [3]

Tropical storm Camille was first sighted 500 miles south of Miami on Thursday, August 14, 1969. The following day Camille became a hurricane, and on the next day (Saturday) a hurricane watch was issued from St. Marks, Florida to Biloxi, Mississippi. As the storm moved northwest in the Gulf of Mexico, it was expected to turn northward, but persisted more westerly. Consequently, warnings were shifted westward: the first warnings were for the Florida Panhandle area, then extended to include Biloxi, and then to Grand Isle, Louisiana. Early Sunday morning (August 17) Camille was 250 miles south of Mobile, Alabama, and residents of the eventual landfall area were being advised to evacuate (with predictions of 15–20 foot storm tides). The worst hurricane in most residents' memories had struck in 1947 and served as a point of reference. Moving at about 15 m.p.h., Camille made landfall just west of Pass Christian, Mississippi at 11:00 Sunday night. The storm surge was the highest on record – almost 25 feet – and winds were estimated to have climbed up to 200 m.p.h., with 150 m.p.h. gusts extending 50 miles laterally. One-hundred forty deaths were reported, 5,000 homes were destroyed, and 12,000 homes were heavily damaged.

Researchers from Mississippi State University interviewed approximately 400 respondents four to six weeks after the hurricane had struck. All interviews were in Harrison County, Mississippi, including the hardest hit area and extending 25 miles eastward. Interviewing was confined to an area within a few blocks of the water's edge (Wilkinson and Ross, 1970).

Eloise [4]

Late on Tuesday, September 16, 1975 tropical storm Eloise intensified to hurricane strength near the Dominican Republic. Subsequently, the cyclonic system diminished in power, but after crossing the Yucatan Peninsula on the 21st, Eloise reintensified and attained hurricane status again on Monday, the 22nd. At that time the storm was 350 miles south-southeast of New Orleans and had been moving to the north-northwest. Shortly after that, a little more than 200 miles south of New Orleans, Eloise turned north-northeasterly. National Hurricane Center advisories made the storm appear to slow its forward speed, then turn more easterly, then northly than was actually the case. Warnings issued early on the 22nd from Grande Isle, Louisiana to Apalachicola, Florida were extended eastward to include Cedar Key, Florida shortly after midnight. At 9:45 p.m. on the 22nd a National Weather Service statement advised relocation from low-lying places in the area which was eventually struck hardest, and 10-foot above normal tides were forecast.

Landfall occurred at 7:00 a.m. on Tuesday, September 23, halfway between Fort Walton Beach and Panama City Beach, Florida (60 miles east of the center of the warning area delineated on the morning of the 22nd). Maximum winds were estimated at 125 m.p.h., and the surge height reached 12–16 feet in some places. Peak surge lasted only 30 minutes as the hurricane moved forward at almost 25 m.p.h. Possibly because the eye of the storm and its most destructive quadrant passed over a realtively undeveloped area and because it struck after the Labor Day peak in tourism, no deaths were attributed directly to Eloise. Destruction in Fort Walton Beach and especially Panama City Beach resulted in $ 100 million in damages. An estimated 100,000 people from an area extending as far west as Mississippi evacuated. Eloise was the first major hurricane to affect Panama City this century; Agnes was espected to strike the area in 1972 but passed well to the east, prompting business interests to threaten a lawsuit against the National Weather Service as a result of tourists avoiding the area after hearing the "false" warnings.

A group at Mississippi State University, working with the National Weather Service since 1974, had prepared an interview schedule for use in a post-hurricane situation, and Weather Service personnel put it into practice just a week after Eloise struck. Two-hundred fifty interviews were conducted in the Fort Walton Beach-Destin area, and approximately 125 were gathered in Panama City Beach (Windham et al., 1977).

As part of a Florida Sea Grant study of the social impact of Eloise, a group from Florida State University also conducted interviews dealing with warning response. Interviews with 200 residents of Panama City and Panama City Beach were effected three months after the hurricane (Baker et al., 1976).

Summary

The storms studied had three principal characteristics in common: (1) they were all major hurricanes, (2) they all presented landfall forecasting problems, with warnings being revised a number of times, and (3) despite the early errors in exact landfall location, all three storms afforded lengthy periods of monitoring. They were also different in several respects:

(1) each struck a distinctly different coastal area, (2) each struck at a different time of day, and (3) the fatalities varied widely.

PREDICTORS OF EVACUATION

Over 75 variables were tested to assess their ability to predict evacuation. They have been grouped into 13 categories for the ensuing discussion.

Sources of information (Table 1)

Most coastal residents receive the majority of their information about threatening hurricanes from the media – primarily television, followed by radio. Source of information has little or no association with evacuation, however. How people first hear about a storm, how they receive their monitoring information about it, and how they first hear that it is expected to strike their area appear to make no difference. Radio broadcasts were found to be slightly more strongly related to high evacuation rate than television in one study, but the results did not replicate in a second investigation.

Evacuation advisements (Table 2)

Respondents who recalled being advised to evacuate before Carla were significantly more

TABLE 1

Sources of Information vs. Evacuation

Variable	Study	df[a]	$P(\chi^2)$[b]	τ_b[c]
How 1st heard of storm	Eloise (FSU)	1	NS	
Primary source of information (radio vs. TV)	Eloise (FSU)	1	NS	
	Eloise (FSU)	1	NS	
Source of 1st warning (radio vs. TV)	Carla	1	.001	.01
	Eloise (FSU)	1	NS	
(media vs. other)	Carla	1	NS	
	Eloise (FSU)	1	NS	

[a] df indicates the degree of freedom in the contingency table. 1 + df gives the number of categories of the predictor variable.
[b] $P(\chi^2)$ indicates the significance level of the χ^2-test of independence performed on the data. NS indicates non-significance at the .05 level.
[c] τ_b indicates a measure of the strength of association in the contingency table, Goodman and Kruskal's τ_b.

TABLE 2

Evacuation Advisement vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Advised to leave	Carla	1	.001	.11
	Eloise (FSU)	1	NS	
Officials went through neighborhood	Eloise (FSU)	1	NS	
Source of orders or advice	Carla	2	.01	.03

TABLE 3

Storm Watching vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
When 1st heard about storm	Eloise (FSU)	1	NS	
Care in monitoring storm	Carla	1	NS	
Length of time storm monitored	Eloise (MSU)	2	NS	
Kept tracking chart	Eloise (FSU)	1	NS	
Frequency of media monitoring	Eloise (FSU)	2	NS	
Increase in media monitoring	Eloise (MSU)	2	NS	
Lateness of media monitoring	Eloise (FSU)	1	NS	
	Eloise (MSU)	3	NS	
Warnings verified	Carla	1	.001	.01

likely to leave than those who had no such recollection, but the finding was not evident in Eloise. Officials going through a neighborhood "ordering" evacuation was not found to have made a difference in Eloise either. In Carla civil defense personnel were slightly less successful in eliciting evacuation than public officials.

Storm watching (Table 3)

The attention devoted to monitoring the threatening hurricane is almost totally unrelated to whether one evacuates. It does not matter (1) how early one becomes aware of the hurricane, (2) how carefully (self-reported) one monitors the storm, (3) how long one monitors the storm, (4) whether one keeps a hurricane tracking chart, (5) how often one seeks media information about the storm, (6) whether one watches or listens to media weather information more frequently than usual, or (7) (in a special case when landfall occurred at 7 a.m.) whether one stayed up late monitoring the media the night before.

People who had a second source verify warnings of Carla were slightly more likely to evacuate than people who did not have verification of the information.

Belief storm would hit (Table 4)

Coastal residents who believe a hurricane will strike their area might reasonably be expected to be more likely to evacuate than residents who do not believe the storm will strike. Data tend to bear this out, but the relationship is weak and pertains only shortly before landfall. No time frame was reported for the Carla study, but "believers" were slightly more likely to evacuate. Ten or more hours before actual landfall, respondents to the Camille and Eloise (MSU) surveys could not be differentiated with respect to eventual evacuation on the basis of whether they believed the hurricane would strike. Three to seven hours before landfall, believers were a little more likely to leave. The FSU study of Eloise found no difference eight hours before landfall.

TABLE 4

Belief Storm Would Hit vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Expected direct hit	Carla	1	.001	.01
Expected direct hit at:				
14 hours before landfall	Camille	1	NS	
10 hours before landfall	Camille	1	NS	
4 hours before landfall	Camille	1	.01	.03
8 hours before landfall	Eloise (FSU)	2	NS	
18 hours before landfall	Eloise (MSU)	1	NS	
10 hours before landfall	Eloise (MSU)	1	NS	
7 hours before landfall	Eloise (MSU)	1	.01	.02
3 hours before landfall	Eloise (MSU)	1	.01	.03

Expectation of damage (Table 5)

A much better predictor of evacuation is how bad one expects the storm to be. Those who expected wind damage to be high in Camille were most likely to leave, as were those who expected winds to do damage to roofs in Eloise. People who thought winds would be strong enough to overturn automobiles were even more likely to evacuate, and to a lesser extent the same was true of people who expected surge from Eloise to reach their house. Related to expected water damage is how high one believes his house to be above mean sea level. Mississippi residents who believed their elevation to be lower than 15 feet above mean sea level were most likely to evacuate before Camille. Respondents in the "don't know" category were also highly probable to leave their homes.

Confidence in weather forecasting (Table 6)

Only one of the four studies attempted to relate confidence in weather forecasts to evacuation, and the results are confusing. People who believe that weather reports are usually accurate were more likely to evacuate than people who do not believe in forecasts, but the frequency with which respondents listen to forecasts was unrelated to evacuation.

TABLE 5

Expectation of Damage vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Wind damage anticipated	Camille	1	.01	.03
Wind damage anticipated to roofs	Eloise (MSU)	1	.001	.03
Wind damage anticipated to autos	Eloise (MSU)	1	.001	.06
Water damage anticipated	Camille	1	.001	.11
	Eloise (MSU)	1	.001	.03
Perceived elevation	Camille	5	.001	.06

TABLE 6

Confidence in Weather Forecasting vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Confidence in weather forecasts	Eloise (FSU)	1	.01	.03
Listen to weather forceasts often	Eloise (FSU)	3	NS	
Confidence in hurricane landfall	Eloise (FSU)	3	.01	.06
		1	NS	
Confidence in hurricane severity	Eloise (FSU)	3	.003	.08
		1	NS	

There is strong evidence that confidence in forecasts regarding a hurricane's landfall location and severity is associated with evacuation, but the meaning of the relationship is unclear. Respondents who felt that landfall predictions are almost always right or rarely right (the opposite extremes) were least probable to leave. Those in the "usually right" and "sometimes right" categories evacuated more frequently. When Table 6 is collapsed to two categories of confidence ("almost always/usually," "sometimes/rarely") the association with evacuation vanishes. People who feel that predictions of hurricane severity are almost always right were the least likely to evacuate, and the "sometimes right" category had the highest proportion of leavers. Again, when Table 6 is collapsed to only two categories of confidence, no relationship is detected.

Recall of forecast information (Table 7)

Regardless of time period before landfall, respondents who recalled the forecast wind speeds of Camille and Eloise within 10 m.p.h. were no more or less likely to evacuate than those who could not recall the forecast wind speed. In Eloise, people who recalled the forecast most accurately were less prone to evacuate than those who either overstated or understated the forecast. Residents who could recall what the predicted surge height had been 10 hours before landfall could not be differentiated from those who could not recall, but those who recalled the four-hour predic-

TABLE 7

Recall of Forecast Information vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Recall of predicted wind (w/in mph)	Camille	1	NS	
	Eloise	1	NS	
Recall of predicted wind (over/under)	Eloise (MSU)	2	.01	.02
Recall of predicted water (w/in 2 ft.):				
10 hours before landfall	Camille	1	NS	
4 hours before landfall	Camille	1	.05	.01

tion were actually least likely to have left. The latter counter-intuitive finding may be attributable to the fact that most leavers had evacuated more than four hours before landfall, thus they would be less likely to have heard the surge prediction made at that late hour.

Knowledge about hurricanes (Table 8)

One commonly espoused solution to enhancing evacuation is public education; i.e., making the public more aware about hurricane dangers and proper response to warnings (see Christensen and Ruch, 1977). The effect which such programs have on evacuation is questionable, although they may be useful in bringing about behaviors other than those tested for in this review. In point of fact, knowledge about hurricanes and hurricane safety rules were consistently not found to be associated with evacuation behavior. The only variable in this category which might constitute an aspect of hurricane awareness that was related to evacuation was knowledge of one's homesite elevation. Respondents who could give their elevation within one foot accuracy were considerably less likely to evacuate than people who either overestimated or underestimated their elevation.

(Recall from Table 5 that residents who believed their elevation to be low or did not know their elevation were most probable to leave.) Knowledge of hurricane terms, familiarity with hurricane safety rules distributed by the National Oceanic and Atmospheric Administration, and awareness of the existence of or location of public shelters were all *un*-associated with evacuation.

Previous hurricane experience (Table 9)

Measurement of an individual's previous hurricane experience is difficult because the measure usually depends on the respondent's recall and beliefs. A common error is for

TABLE 8

Knowledge about Hurricanes vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Knowledge of house evaluation	Camille	1	.001	.04
Number of hurricane terms known	Camille	1	NS	
Number of hurricane safety rules known	Camille	1	NS	
	Camille	2	NS	
Had seen copy of rules	Camille	1	NS	
Had heard of list of rules	Camille	1	NS	
Knowledge of public shelters	Eloise (FSU)	1	NS	
Knew definition of "warning"	Eloise (MSU)	1	NS	
Knew definition of "low-lying-area"	Eloise (MSU)	1	NS	
Possessed copy of safety rules	Eloise (MSU)	1	NS	
Had heard of list of rules	Eloise (MSU)	1	NS	

TABLE 9

Previous Hurricane Experience vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Previous disaster experience	Carla	1	NS	
Previous hurricane experience	Camille	1	NS	
Number of hurricanes experienced	Camille	1	NS	
Previous hurricane experience	Eloise (FSU)	1	NS	
Recency of hurricane experience	Eloise (FSU)	2	NS	
Previous hurricane experience	Eloise (MSU)	1	NS	
Severity of previous hurricane	Eloise (MSU)	2	.02	.02
Damage in previous hurricane	Eloise (MSU)	1	NS	
Family injury in previous hurricane	Eloise (MSU)	1	NS	
Evacuated in previous hurricane	Carla	1	.001	.03

coastal residents to believe they were affected by hurricanes to a greater degree than they actually were. That is, they might have only been on the fringes of a hurricane system, receiving gale-force winds, but believe they experienced the storm's full strength. All the variables in Table 9 are subject to that sort of error to varying degrees. Furthermore, all three study areas are on the Gulf Coast, the region of the United States which had the greatest frequency of hurricane activity during the 1960's and early 1970's. Thus, to some extent, the aggregate "background experience level" for the area as a whole was higher than other parts of the U.S. coastline during the same period.

Taking the results at face value, however, it seems clear that presence or absence of previous experience, *per se*, is unrelated to evacuation. The same is true with respect to the number of hurricanes experienced, recency of one's experience, and whether damages or injuries were suffered by one's household. Severity of hurricanes experienced previously was related to evacuation in Eloise, but those who had experienced a major hurricane (which meteorologists classify as major) were less likely to evacuate than respondents who had experienced a low-intensity hurricane or who had no previous experience. Residents who had evacuated in previous hurricanes were also the most probable to evacuate in Carla.

Length of residence (Table 10)

Two concerns have been expressed frequently that relate the length of time an individual has lived in a coastal area to his or her probability of evacuating: (1) over three-fourths of the residents of coastal counties have never experienced a major hurricane due to their short period of residence, and (2) some coastal areas have had no major hurricane for so long that long-term residents may be complacent (Hebert and Taylor, 1975). The experience

TABLE 10

Length of Residence vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Number of years lived in area	Camille	1	NS	
	Eloise (FSU)	1	NS	
	Eloise (MSU)	1	.01	.02
Number of years lived in home	Camille	1	.05	.01

issue was discussed in the previous section; the relationship between residence period and evacuation is unclear, but probably weak.

One of the four studies on which this review is based (Windham et al., 1977) reported evidence of a strong association between length of residence and evacuation, asserting that Wilkinson and Ross' (1970) Camille data also supported their finding. The generalization (labeled the "experience-adjustment paradox") indicated that newer residents were more likely to evacuate than residents who had lived in the study area for a longer period (five years or more). The Mississippi State study of Eloise does reveal a weak association consistent with the "paradox," but the Florida State survey found no relationship, and the published Camille data, analyzed again for this review, indicated no association either. The Camille study does, however, suggest that people who had lived at the same address (not just the study area) for less than five years were slightly more likely to evacuate than people living at the same address five years or more.

Site characteristics (Table 11)

An encouraging finding is that people who most need to evacuate appear to be the most

TABLE 11

Site Characteristics vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Homesite elevation	Camille	4	.001	.19
Geographical area of risk	Camille	3	.05	.02
	Eloise (FSU)	2	.001	.09
	Eloise (MSU)	4	.001	.11
Damages sustained	Camille	3	.001	.05
	Eloise (FSU)	2	NS	
	Eloise (MSU)	2	NS	
Age of house	Camille	3	.05	
Construction materials	Camille	3	.05	.02
Number of stories	Camille	1	.01	.02
Type of dwelling	Eloise (MSU)	2	NS	

likely to leave, although variables in this section may be confounded with other predictors of response to an extreme degree. Elevation of the respondent's home above mean sea level exhibited one of the strongest associations with evacuation produced by any of the four studies. The relationship was clearly monotonic with people living in lowest-lying areas being the most likely to leave. Recalling Table 8, respondents who were most knowledgeable about their residential elevation might have been those whose elevation was highest. Unfortunately, the variable was reported only in the Camille study, although other – less straightforward – variables suggest the same conclusion. In Camille evacuation was greatest in the hardest hit area (Pass Christian and Long Beach). In the Eloise study reported by Windham et al. evacuation was considerably higher in the beach areas (Okaloosa, Destin, Panama City Beach) than in the more protected areas fronting Chotawhatchee Bay. The Florida State survey following Eloise indicated that evacuation was highest in the beach areas, then the bay-bayou areas, and finally, inland areas.

Damages sustained were related to evacuation only in Camille. In Eloise, however, the more severe damage was concentrated in the beachfront area of Panama City Beach, and owners of those structures were generally unavailable for interview either because they were not permanent residents of the area or because the structure was damaged beyond habitability. Thus, there was relatively little variation in damages experienced by most of the sample respondents.

The Camille study included several variables relating to construction attributes of the respondent's house. Age of the house was not associated with evacuation, but people living in two-story structures were less prone to leave than people living in one-story buildings. Mobile homes were categorized as a type of construction material (rather than wood, brick, veneer, or masonry), and their dwellers were the most probable to evacuate. One of the Eloise investigations (MSU) classified mobile homes as a type of dwelling (vs. single-family and apartment) and found no relationship with evacuation.

Demographic characteristics (Table 12)

The most consistently collected data might be grouped loosely under the heading of demographic attributes of the respondent. Certain characteristics – sex, marital status, and occupation – were unassociated with evacuation in any of the four studies. Education was related to leaving in only one of the four studies in which it was tested; income, number of children in the respondent's family, and number of families in the respondent's dwelling were tested and found associated with evacuation only in the Carla study. Whether the respondent owned or rented his or her dwelling was investigated in three of the studies but found to predict evacuation in only one.

Age is frequently mentioned as a critical variable because of the restricted mobility of older people. The Camille and Eloise surveys reported by Mississippi State revealed no relationship between age and leaving. The Carla study found a weak association, with residents over 60 being slightly less evacuation-prone than people between 40 and 60, and both groups being less likely to leave than respondents between 20 and 40. The authors of the report noted, however, that although the older age group was least probable to evacuate, the respondents stated that they chose voluntarily not to leave, and were not forced to stay in their homes because of low mobility. The Baker et al. survey after Eloise indicated that when age was classified into five categories, the youngest group (18–25) was most likely to evacuate and the oldest group (over 60) was second

TABLE 12

Demographic Characteristics vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Age	Carla	2	.02	.01
	Camille	2	NS	
	Eloise (FSU)	4	.03	.01
		2	NS	
	Eloise (MSU)	2	NS	
Education	Carla	2	.001	.03
	Camille	2	NS	
	Eloise (FSU)	2	NS	
	Eloise (MSU)	2	NS	
Income	Carla	3	.001	.04
Occupation	Carla	5	NS	
	Camille	7	NS	
	Eloise (MSU)	7	NS	
Marital Status	Camille	1	NS	
	Eloise (FSU)	1	NS	
	Eloise (MSU)	1	NS	
Sex	Carla	1	NS	
	Camille	1	NS	
	Eloise (FSU)	1	NS	
	Eloise (MSU)	1	NS	
Number of children in family	Carla	3	.001	.01
Number of families in building	Camille	1	.01	.03
Health	Eloise	2	NS	
Owner/renter	Camille	1	NS	
	Eloise (FSU)	1	NS	
	Eloise (MSU)	1	.01	.02

TABLE 13

Miscellaneous Variables vs. Evacuation

Variable	Study	df	$P(\chi^2)$	τ_b
Extent of neighborhood evacuation	Carla	2	.001	.24
	Camille	1	.001	.05
	Eloise (FSU)	3	.001	.13
Felt role conflict	Carla	1	NS	
Degree of discussion	Carla	1	.001	.02
With whom discussed	Carla	1	.01	.01
Number of emergency preparations	Eloise (FSU)	1	NS	
Home weather instruments	Eloise (FSU)	1	NS	
Boat ownership	Eloise (FSU)	1	NS	
Church attendance	Eloise (FSU)	1	NS	

most probable (although appreciably less so than the first group). When categories are collapsed to conform to those reported in Table 12 for the other three studies (18–40, 41–60, over 60), no significant difference in evacuation rate existed for the three groups.

Miscellaneous variables (Table 13)

Several additional variables fit into no general category on the basis of commonality with other variables. One of the best predictors consistently identified is the extent of evacuation which took place in the respondent's neighborhood. People who lived in areas from which most of their neighbors evacuated were also likely to have evacuated. One explanation traditionally proposed for this association is a conformity phenomenon: people are reluctant to leave if their neighbors are not leaving and are reluctant to stay if their neighbors are not staying. The variable is hopelessly confounded with other predictors, however. The association probably reflects the fact that evacuation rate was greatest in the most hazardous areas and that Civil Defense or other officials advised or ordered evacuation from those areas. Thus, if a respondent evacuated from a neighborhood in which most others did the same, he or she and the others may have been motivated primarily by a commonly perceived need to leave and may have acted independently of one another.

The Carla study looked into a number of elements of the respondent's decision process. Feeling an obligation to fulfill roles (such as professional) which would prevent someone from evacuating apparently did not keep him or her from leaving. Those who discussed the evacuation issue with others a great deal were more likely to evacuate, and those who had discussions with people outside their family were more probable to leave than those who had discussions with family members only.

The number of emergency preparations made by the respondent, operation of home weather instruments, boat ownership, and church attendance all failed to exhibit a relationship with evacuation.

CONCLUSIONS

The list of variables selected and analyzed for this review is not totally exhaustive of those reported in the published reports, but it is extensive and representative. Many other warning response issues such as time of evacuation and how far away people evacuated are not addressed. More discussion, qualification, and explanation of findings reported here could have been included in each predictor variable group, but the cost would have been a much longer article. The general comments below may serve the same purpose at lesser length.

Strength of relationship

The four studies are characterized by failure to identify consistently strong predictors of evacuation. The first of the studies (Moore et al.) is replete with significant χ^2-tests, but the huge sample size (1,500) overstated the importance of the variables. Indeed the best measure of strength of relationship in contingency tables is open to debate. Goodman and Kruskal's τ_b allows comparison of two or more tables regardless of sample size or the number of categories involved, and it satisfies the convention of a value of zero implying complete lack of association and a value of one implying perfect association. In this case the value indicates the reduction in one's probability of error in predicting whether or not a respondent evacuated, if one knows something about the respondent with respect to the predictor variable in question. From Table 13, for example, one would be 24% less likely to err in predicting whether a respondent evacuated in Carla, if it were known to what extent the respondent's neighborhood evacuated.

Of the 120 contingency tables reviewed here, a third of them produced relationships significantly greater than zero (at the .05 level or better). But only 14 of the significant tables yielded a value of τ_b greater than .05 and only six gave a value greater than or equal to .10. The strongest relationship was .24.

A ten percent reduction in error in predicting evacuation is less than overwhelming, but the τ_b measure is more arbitrary than it may appear. Goodman and Kruskal's λ, a similar "reduction in errors" measure, usually gives a larger value than τ_b, but sometimes gives a value of zero when an association is actually present. Some observers might feel the "proportional reduction in errors" understates the difference which might exist across categories of the predictor variables. For example, in Eloise, 85% of respondents who believed water would reach their house evacuated, compared to 66% of those who didn't believe it would. The τ_b value was only .03.

Causality, control, and multiple effect

The matters of association, prediction, and relation are quite distinct from causality. As poor as existing research is at identifying predictors, in no case can it be said that the studies have revealed what causes evacuation. Surely much of the association of certain variables with evacuation is causal, but previously published inquiries have yet to demonstrate that assertion.

The Carla study in a few isolated cases did "control" for one predictor variable while testing for association between another predictor and evacuation. It thereby sometimes produced qualifications for the relationship detected: discussion was associated with greater evacuation only if people were not ordered to evacuate, for example. Such a test is the exception rather than the rule, however, and the formal process of testing for higher order interactions is unreported in hurricane evacuation literature. Whereas individual variables do not predict evacuation well, it is unknown how well combinations of variables already tested can predict when acting together.

Measuring evacuation

Part of the failure to identify powerful predictors may stem from inappropriate measurement of evacuation. All four of the studies reviewed simply measured whether the respondent left home seeking safety from the hurricane. (The Carla study differentiated between leavers who went to local shelters and those who went out of town, but the two groups were combined for this review to make the studies comparable.) It is tempting to presuppose that evacuation is the proper warning response and that it is the behavior which should be maximized.

It is probable, however, that some of the stayers did not need to evacuate and that some of the leavers would have been safe staying at home. Thus, evacuation may not always be the proper response. Deciding who did not need to evacuate is tricky business, and employing hindsight is cheating because the respondent did not have benefit of such knowledge in reaching his evacuation decision. Storm surge was underestimated in Camille and Eloise, and "hurricane proof" houses have been demolished by hurricanes. Caution is certainly advisable. In the four studies reviewed, few of the respondents probably should have stayed home, so the measurement problem may have been small.

A more discriminating measure of evacuation might also be revealing. For example, how early an evacuee leaves, how far he or she goes, and what form of shelter he or she seeks might be associated with predictors more strongly than the coarser indication of whether the respondent left or not.

Future directions for research

The most reassuring conclusion evident in the surveys is that the most risky areas have been the most extensively evacuated. The studies reveal little, though, that will be effective in enhancing the likelihood of evacuation. This is not to belittle the importance of the previous work, however. It has indicated limitations on the effects which might otherwise have been expected to result from manipulation of certain variables, and it has laid the groundwork for further efforts. Further efforts to identify correlates to evacuation should consider the following suggestions.

1. The correlates should be useful (i.e., manipulatable). A principal motivation for warning response research is to provide clues for bringing about more rational response to warnings. Identifying changes in dissemination procedures which might result in greater evacuation would be more useful than discovering personality traits which correlate with evacuation, for example.

2. Analyses should be more sophisiticated. The χ^2-test on two variables reveals too little; at the very least, interpretable measures of the strength of the relationship should be computed. Variables should be treated in combination to a) partial out the effect of inter-correlated predictors, b) test for interactions, and c) assess multiple prediction.

3. Controlled laboratory experiments should be pursued. Controlled experiments, despite limitations because of their lack of certain aspects of realism, may nevertheless provide indications of the relative importance of variables expected to affect evacuation and which are inter-correlated outside the laboratory. While some designs may be elaborate, others may consist of pencil-and-paper information-integration tasks.

4. Rather than simply assessing evacuation, a measure of appropriateness of response should be used. Ideally, a team of hurricane experts should judge, given the same information the respondent possessed, whether he or she should have evacuated. Alternatively, an area in which all residents should have evacuated might be employed as the sampling frame.

A multi-faceted study currently underway at the University of Minnesota is attempting to satisfy several of the above conditions. Predictor variables are combined and analyzed via discriminant analysis, a computer game (dealing with tornado warnings) is used to operationalize an experimental design, and a rough effort is made to evaluate whether evacuation is appropriate for respondents (Carter et al., 1978). Such steps are laborious and sometimes expensive, but given the shortcomings of previous surveys, such steps appear necessary if advances are to be made in enhancing evacuation.

NOTES

1 Generalizations produced by research into response to warnings of other hazards (Mileti, 1975) may in some cases apply as well to hurricane situations, but certainly there are a number of characteristics unique to hurricanes. Pertinence of findings from evacuation studies involving hazards other than hurricanes will not be included in this discussion.

2 Descriptions of the meteorological and warning aspects of Carla come from Moore et al. (1963) and Dunn (1962).

3 Descriptions of the meteorological and warning aspects of Camille come from Wilkinson and Ross (1970) and Simpson and Sugg (1970).

4 Descriptions of the meteorological and warning aspects of Eloise come from NOAA (1975) and Hebert (1976).

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