Public Response to Tornado Warnings: A Comparative Study of the May 4, 2003, Tornados in Kansas, Missouri, and Tennessee

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SUMMARY

On May 4, 2003, a major storm system moved across the Midwest, spawning numerous tornados in the states of Kansas, Missouri, and Tennessee. These tornados caused heavy damage to both rural and urban communities. In an attempt to determine whether residents were sufficiently warned and able to seek shelter, surveys were conducted in 18 communities of Kansas, Missouri, and Tennessee impacted by the May 4, 2003, tornados. This analysis of survey data reveals that tornado warnings were adequate and timely in large communities. The same is not true for small communities, particularly for rural areas, where tornado warnings also significantly differ across timing and sociological factors. Several suggestions are made to improve warning systems in smaller communities.

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INTRODUCTION

A series of tornados pummeled Kansas, Missouri, and Tennessee on May 4, 2003, killing 37 people and leaving a swath of destruction one-half mile wide in some places (NWS 2003). These tornados were part of a large storm system that hit the Midwest, spawning twisters in South Dakota and Nebraska as well. This storm system also caused damage in Iowa, Nebraska, Arkansas, and Kentucky. This system was the deadliest since May 3, 1999, when 45 people were killed by 73 tornados that flattened parts of Oklahoma and Kansas (Hampton 1999). Though sirens warned citizens in many towns before the tornados struck on May 4, 2003, the size and sheer strength of the event resulted in casualties nonetheless.

These early May tornados were blamed for at least 19 deaths in Missouri, seven in Kansas, and 11 in Tennessee. In Kansas, seven counties (Cherokee, Crawford, Labettee, Neosho, Leavenworth, Miami, and Wyandotte) and six communities (Kansas City, Columbus, Franklin, Galena, Girard, and Ringo) were severely affected (Figure 1). Each one of these communities experienced at least one death. More than 1,000 structures were damaged in Kansas, nearly 70 people were injured, and losses were estimated at $22 million for property damage (Manhattan Mercury 2003).

In Missouri, widespread losses were reported in 17 counties (Barton, Camden, Cass, Cedar, Christian, Clay, Greene, Jackson, Jasper, Lawrence, and Platte) of central and southwestern parts of the state. Thirteen communities of different sizes were ravaged by the May 4, 2003 tornados

(Figure 1). Of these, seven communities experienced at least one death. According to a preliminary estimate, nearly 2,000 buildings were damaged and nearly 100 people injured in Missouri. In monetary terms, the state experienced property damage totaling over $100 million (Manhattan Mercury 2003).

One of the hardest hit areas was Madison County, Tennessee, where 11 people were killed. Jackson, the county seat with a population over 60,000, was severely impacted by the May 4, 2003 tornados which destroyed a portion of the downtown area. According to the Federal Emergency Management Agency (FEMA), the tornados injured 117 and damaged an estimated 1,600 homes and businesses (Budde 2003). The tornado that hit Jackson gouged a 65-mile long path across western Tennessee. This system also hit Neely Station (Denmark) and Lexington. Both are located close to the city of Jackson (Figure 1).

RESEARCH PROBLEMS

Since the mid-1970s, the federal government has placed great emphasis on hazard mitigation which involves actions taken before a disaster to decrease vulnerability. Mitigation attempts to minimize loss of life, injury, and property damage and provide passive protection during disaster impact (Odeh 2002; Tierney et al. 2001; Tobin and Montz 1997). Mileti (1999) classified all hazard mitigation measures into five groups and warning is identified as one of them. Since mitigation has become the cornerstone of the nation's approach to addressing natural hazards, there have been significant improvements in warnings for tornados. In 1978, warnings were issued for 22% of tornados and the average warning time was three minutes. Now the percentage has risen to over 90 and the lead time up to 30 minutes (see Golden and Adams 2000; Mileti 1999).

The aforementioned improvement is the result of the federal government's investment of millions of dollars in advancing our ability to detect and predict tornados. The WSR88-D Doppler weather radar, Geostationary Operational Environmental Satellites (GOES), Warning Decision Support System (WDSS), and Automated Weather Interactive Processing System (AWIPS) are just some of the advances that lead to improved warnings. There has also been an increased involvement of both private and public agencies involved in the process of detection and issuance of warnings. Additionally, better training for forecasters, improved local storm spotter networks, and awareness campaigns are responsible for significant improvements in tornado warnings in the U.S.

While hazard warning has greatly improved over the last two decades, many small- and medium-sized communities lag in their ability to provide citizens with effective warning message (Mileti 1999). The size of the community determines the type of warning system that is in place as well as the qualifications of the emergency personnel needed to effectively disseminate the message to the population at risk. The tornados that occurred on May 4, 2003 struck both large and small communities. Five cities of the Greater Kansas City Metropolitan Area (GKCMA) were severely impacted by these tornados. GKCMA includes more than 36 cities, spans 11 counties, and contains about 1.6 million people. Tornados also struck several small communities. One such community was Franklin, Kansas with a population of about 375.

The hazards literature states that tornado warning systems differ in many ways between large cities and small rural communities (see Cross 2001). The former are generally equipped with advanced tornado warning systems, while the latter rely more on traditional systems such as siren systems and storm spotters or chasers who relay information to local police and/or media. Traditional warning systems tend to be less immediately responsive and fail to capture the "big picture" relative to radars of large cities which can quickly create a precise image of a developing storm or tornado system. Also, small rural communities may use the siren system for other purposes. For example, Sabetha, a small town of Kansas with a population of 2,286, sounds its siren system three times a day. As a result, residents become accustomed to the sound of sirens and may not regard it as a tornado warning.

Population size may also explain differences between large and small communities with respect to tornado warning systems. Unlike large cities, small cities and towns generally do not receive federal grants for many improvements, including storm warning systems. The federal government recognizes that protecting the large more densely populated major cities is vital since tornados can usually create more damage and the potential for loss of life is greater there. Large cities also have TV stations which possess various modern and expensive weather forecasting equipment such as Doppler radar. Most small cities and rural communities do not have a local weather or broadcasting channel. Such communities also rarely have direct access to National Oceanic and Atmospheric Administration (NOAA) Weather Radio (NWR) broadcasts (see Golden and Adams 2000).

Demographic, social, political, and economic characteristics of residents in large and small communities also differ. Such variations pose different threats for people of different sized communities. Large cities have greater resilience, as they have both large populations at risk and the greatest resources and political influence to deal with hazards and disasters. Small communities have far smaller populations at risk, but often have a higher proportion of the population that is vulnerable (Cross 2001). Additionally, community differences are thought to play significant roles in compliance with hazard warnings and behavior of potential victims prior to the occurrence of a significant event (see Gruntfest 1987).

OBJECTIVES

While a large number of studies (e.g., Balluz et al. 2000; Golden and Adams 2000; Gruntfest 1987; Liu et al. 1996) have examined the dissemination, meaning, effectiveness, and response to tornado warnings, no study as of yet has used a comparative approach to investigating tornado warning differences among communities of different sizes. This study will examine whether access to tornado warning and information significantly differ between survivors of the cities of GKCMA and other communities of Kansas, Missouri, and Tennessee devastated by the tornados of May 4, 2003. More specifically, this research will address the following questions:

- Did survivors receive the tornado warning(s), and if so, by what means and with how much lead-time?
- What did survivors do when they received a warning or learned of the tornado?
- What are survivors' opinions about tornado warning systems?

Survivors' access to tornado warnings will be analyzed by their place of residence, and in respect to their socio-economic and demographic (e.g., age, gender, marital status, race, employment, level of education, and income) characteristics. One additional variable, time of issuance of the tornado warning, will also be included in this analysis. By analyzing survivors' traits, this study will provide useful information for further improvements in tornado preparedness and warning - especially in small communities.

METHODOLOGY

Data Collection Procedures

Two weeks after the event, the authors of this report traveled across the states of Kansas, Missouri, and Tennessee to observe the devastation caused by the May 4, 2003, tornados and to interview the tornado victims and survivors to determine the types of warnings they received and whether they had enough response time to seek shelter. Although the research team visited 26 communities, field interviews were conducted in 20 of the communities (Figure 1). Contrary to the initial report of the NWS, the remaining six communities (Plate City, Missouri; Parkville, Missouri; Monett, Missouri; Atwood, Tennessee; Paris, Tennessee; and Clarksville, Tennessee) did not experience severe tornado damage on May 4, 2003. Among the selected communities, five are considered rural. These communities are: Verona, Liberal, Columbus, Badger Road (near Galena), and Neely Station (Denmark). The first two communities are located in Missouri, the next two in Kansas, and the last one in Tennessee.

Field surveys were conducted in two phases: from May 17-23, 2003, and on May 31, 2003. In the first phase the research team conducted surveys in 19 communities within the three states. In the second phase the survey was conducted by Bimal K. Paul, Vicki Tinnon Brock, and one research assistant (Frank Holmes) in Kansas City, Kansas. In each selected site, the research team sought to interview residents who had experienced the tornado firsthand. Since the team went to the field two weeks after the event, many disaster victims and survivors were at home either working outside on their properties or cleaning up debris. In all, the team interviewed 143 people using a structured questionnaire. Respondents were randomly selected from the tornado-affected communities and were generally eager to answer questions. They were from locations that encompassed the entire spectrum of damage severity.

In some communities, such as Franklin, Kansas, the research team had no access to homes located at the core of a tornado path. At times, there was no one home during the interview period. Several homes in the core area were declared uninhabitable. The research team was able to identify households with tornado fatalities, but no member of such a household was interviewed for humanitarian reasons. Relevant information was also collected from public officials, emergency personnel, and others at the time of field surveys.

The questionnaire included two broad sections. In the first section, information was collected on tornado warnings and respondents' compliance with those warnings. Respondents' opinions regarding the adequacy and timely issuing of warnings were also sought. For opinion-type questions, a 1-5 Likert Scale, where 1 signifies strongly agree and 5 strongly disagree, was used. A score of 3 infers the respondent is neither particularly dissatisfied nor satisfied. A series of questions were asked regarding participant response to the May 4, 2003, tornados including amount and type of damage caused by the event. In the second section, respondents were asked to provide ancillary information regarding household and individual characteristics. These characteristics included the following: gender, age, and marital and employment status.

Both qualitative and quantitative approaches were employed to analyze the collected data. The survey data was entered into a spreadsheet for analysis. The Chi-square statistic was used to test for significance and to determine relationships between access to tornado warning and respondent characteristics including place of residence and the time of issuance of the warning.

Characteristics of the Respondents

In all, the survey team interviewed 143 people with a structured questionnaire. Fourteen questionnaires were discarded because of incomplete answers. Thus, the analysis in this study is based on 129 completed questionnaires.

Table 1 presents selected socio-economic and demographic characteristics of the respondents. The majority of the respondents were male (58%). This is probably a result of the demographics of the people at the survey sites at the time that the surveys were conducted. The surveys were conducted during the daylight hours when most of the respondents were working or cleaning up debris outside their homes along with their friends and relatives. It was apparent that more men than women were involved in cleaning damaged homes and other structures, including property.

Most of the respondents were married at the time of the survey (Table 1). Slightly over 31% of the respondents were under the age of 45 and slightly over 41% were between the ages of 45-64. The age cohort of those over 64 accounted for approximately 28% of all respondents. As shown in Table 1, the level of education of the respondents is categorized into four classes. More than two-thirds of the respondents received high school and undergraduate degrees.

Nearly half of the total number of respondents were employed and 6.2% were unemployed at the time of survey (Table 1). Nearly one-third of all respondents were retired and the remaining respondents were grouped under the "others" category. This category included students, disabled individuals, and respondents who were either self-employed or employed on a part-time basis. Table 1 shows that the modal gross family income was between $40,000 and $59,999 per year. Nine (7%) respondents did not provide information on household income.

RESULTS

The intensities of tornados that struck the communities selected in this study on May 4, 2003, ranged from F0 to F4 on the Fujita Scale. The width of these tornados differed along their paths from 100 yards to about half a mile. As noted, the tornados hit both rural and urban communities of varying sizes (Table 2). The first major tornado on May 4, 2003, hit Kansas City, Kansas at 4:26 pm and by 6:15 pm all the selected communities in Kansas and Missouri were impacted by tornados.

The tornado outbreak occurred in Tennessee at night on May 4, 2003, and into the early morning hours of May 5, 2003 (Table 2).

The May 4, 2003, tornados either partially or completely destroyed many homes, barns, outbuildings, mobile homes, apartments, businesses, and factories in the study communities. The tornados also damaged vehicles and uprooted trees and poles. They caused extensive damage to buildings in the downtown areas of Liberty, Missouri and Jackson, Tennessee, and demolished those of Stockton, Missouri, and Pierce City, Missouri. The survey data reveals that nearly 91% of the all respondents experienced damage from the tornado. Almost all of these respondents reported that the tornado damaged roofs and sheds, and uprooted trees. Damage estimates ranged from $1,000 to $300,000 depending on the damage that occurred in each location.

Only four respondents reported tornado-related injuries in their households. All these were minor injuries caused by flying debris. In addition to people, eight respondents reported injuries to their pets. Approximately three-quarters of respondents (73%) were home when the tornado struck. The remaining respondents were either at work or away from home shopping, visiting parents, visiting relatives and friends, or returning home. The May 4, 2003, tornados struck most of the communities selected in this study on Sunday early in the evening. Among those respondents who were at home prior to the tornado, 40% of them had no children and an overwhelming majority had no pets. Children and pets usually elicit special attention during damaging weather events. The survey data reveals that at least 10 people took shelter at the houses of the respondents who were at home. Five respondents stated that they took shelter at a neighbors' house at the last moment.

Warnings

The survey data reveals that 115 (89%) of the 129 respondents were aware of tornado before it actually hit their communities. Of the 14 respondents who were not aware of the tornado warning, the most common reason for not being aware was that they were sleeping prior to the tornado hitting their community. This reason was mentioned by respondents in Neely Station (Denmark), Tennessee and Jackson, Tennessee. In these two communities, the tornado hit around midnight and many residents were in bed. Other reasons for being unaware of the warnings were that individuals were in the car or at work. Most of these people were either never aware that there was a tornado threat or they had less than one minute to respond when they did see or hear the tornado. Therefore, 11% of those interviewed never responded to the tornado threat. Although this percentage is not considered high, there is a need to find ways to disseminate tornado warnings to all people at risk in such an event.

However, 33 (26%) of the respondents who were aware of the tornado received a tornado watch issued by the NWS, indicating the potential for the development of tornados. Approximately three-fourths of the respondents, or 73.64%, received a warning that an actual tornado had been spotted or that a funnel cloud was on the ground. Most of the respondents received both tornado watches and warnings prior to the occurrence of the event. Among the respondents who received a warning, the largest proportion of them (75.65%) received the warning from the tornado sirens sounding followed by warning on their local television channel (70.43%). This adds up to more than 100% because the respondents received warning from multiple sources.

Commercial radio warned only 26 respondents (22.61%) and 11 people (9.57%) received warning through word-of-mouth. NWS Weather Radio and telephones were the sources of tornado warning for 5 respondents. Eighteen respondents obtained warning either by looking at the sky or through the local police and fire department personnel who came to their homes and personally told them about the tornado. This occurred in Smithville, Missouri and communities in the GKCMA. In Liberty, Missouri, which is a part of the GKCMA, the local cable company allowed the police to interrupt programming on all channels and advise people to take cover.

A majority of respondents stated that television warnings were important in determining the possibility of their community being struck. They mentioned that this was one of the most important warning sources until the time that power went out. After the power outage, most respondents relied on siren warning systems. Based on conversations with respondents and others present at the time of interviews, it appears that when a tornado is about to hit, people expect to hear a siren. In every community, people seemed to focus on sirens as a means of warning them of an impending tornado. This is an important finding for emergency managers.

After receiving tornado warnings, respondents did a number of things. Thirty-seven percent of the respondents went to their basements. Ten percent each moved to an interior room, a closet, and either to a bathroom or a bathtub for safety. Eighteen percent of the respondents went to storm shelters located within their houses, took shelter at neighbors' houses, or moved to a designated community shelter. In Girard, Kansas, the shelter was located in the local high school, and in Stockton, Missouri, the shelter was in the county courthouse basement. Only five respondents moved to a motor vehicle and drove either to the right or left of the approaching tornado for safety.

Twelve respondents (10%) went outside to see the tornado and to visually verify the tornado threat before taking shelter. This action is not recommended and it involves some risk. Only one person had enough time to run outside and get in a ditch before the tornado hit. The above suggests that 90% of the respondents sought safety immediately after hearing the tornado warnings and that all respondents who received warnings took shelter prior to the occurrence of the tornado. This is an appropriate and recommended measure for all people once they receive tornado warnings.

Although all respondents ultimately complied with the tornado warning, several respondents stated that warnings were such a common occurrence that they tended to be hesitant in their response to the warnings. In the interviews, the elderly tended to be the most nervous about the warnings. Many stated that once they heard the sirens sound, they got scared, but did attempt to take cover. As noted, 10% of the respondents admitted going outside to check out the situation. Some, particularly men, also witnessed the tornado first-hand before taking cover in a basement or shelter. A man in Girard, Kansas tracked the tornado on his scanner and watched it change directions. He immediately sought shelter when he saw the tornado moving in his direction. Women sought shelter in the basement of a Liberal, Missouri home, while the men watched the storm approach. The owner had to go outside to bring in the men at the last minute. A man in Carl Junction, Missouri, watched the oncoming tornado, took shelter, and came out to look when he thought the second siren meant the tornado had passed. He immediately sought shelter again when he saw that the tornado was upon them.

Though the warning lead time was between 1 and 60 minutes for the communities selected in this study, 15% of the 115 respondents said that they had less than 10 minutes of warning time. On the other hand, slightly over two-thirds of the respondents, 68%, had 10 to 20 minutes of warning. The remaining 17% reported 30 minutes or more to respond to the tornado warning. A number of respondents in Jackson, Tennessee, reported that the tornado hit soon after the warning was issued. It is interesting to note that in most communities there was great variation with respect to reported warning lead time. It appears that the respondents answered the question regarding the lead time based on their own perceptions.

A majority of the respondents (55%) strongly agreed and 33% generally agreed that their warning had given them enough time to seek shelter. The remaining 12% either disagreed or strongly disagreed and felt that warning did not give them enough time to seek safety. Many of these respondents, particularly those from rural areas, complained that the sound of the sirens was not clear and loud. Several residents of Jackson, Tennessee, were not able to hear the sirens when they sounded. Another common complaint was that the tornado hit the community quickly.

Respondents were asked if the warnings that the NWS issued prior to tornado occurrence in their community were timely and adequate. Nearly half of the study respondents (49%) strongly agreed that the tornado warning was adequate for their personal circumstances. Another 41% agreed with the above statement. The remaining 10% either disagreed or strongly disagreed that the tornado warning was adequate for their location. When the respondents were asked if they believed that the "overall" tornado warning was adequate, an overwhelming majority of the respondents answered this question affirmatively. Only 10% answered the question negatively. This response is consistent with the other two opinion-type questions asked regarding timeliness and adequacy of tornado warnings in the study communities. Thus, it can be concluded that the early tornado warning systems worked nearly flawlessly on May 4, 2003, and an overwhelming majority of the residents in the impacted communities were pleased with the warning.

Conversations with non-respondents and emergency personnel working in the communities at the time of interviewing also reveal that tornado warnings were issued in a timely manner and reached almost all people in impacted communities. The reports published in the newspapers of the tornado-affected communities also support this view. Because of the adequate and effective warning system, the loss of life and injury was relatively low. Not only were the employees of the National Weather Service in the hardest hit areas actively involved in monitoring and forecasting the approaching tornados, many storm spotters, broadcasters, private-sector meteorologists, emergency managers, and others helped to observe and get the watches and warnings out to the public (see NOAA Public Affairs 2003). The efforts of these groups should be commended for saving many lives.

Aspects of Tornado Warnings

Vulnerability literature indicates that access to tornado warnings depends on community as well as individual/household characteristics. One of the key premises of this study was to determine if tornado warnings differed by place of residence. This was explored in three different ways: the GKCMA versus other tornado impacted communities, large versus small and medium-sized communities, and urban versus rural communities. Access to warning, which is measured in terms of the proportion of the respondents receiving a tornado warning before it hit their community, is expected to differ by place of residence. Warning access was also analyzed by seven socio-economic, racial, and demographic characteristics of the respondents, including their annual household income.

Table 3 presents information on tornado warnings by selected community and respondent characteristics. Since only 14 of the 129 respondents did not receive tornado warnings, both warning status and each one of the selected characteristics is dichotomized to avoid cell values of less than five. Yet, it was not possible to avoid cell values lower than five (see Table 3). If more categories were considered, many cells would contain values less than five. It is worthwhile to mention that use of the chi-square technique is not appropriate when more than 25% of all cells contain values lower than five. However, Table 3 shows a minimal difference in receiving tornado warnings between respondents of the GKCMA and respondents that live in other communities impacted by the May 4, 2003, tornados. The difference, however, was not statistically significant (Table 3). This might be associated with the morphological characteristic of the GKCMA, containing cities of different sizes. Of the five cities of the GKCMA impacted by the tornado, one (Northmoreland, Missouri) has a population of only 399, another (Pleasant Valley, Missouri) has 3,321, two (Gladstone, Missouri and Liberty, Missouri) have slightly over 26,000, and Kansas City, Kansas has close to 150,000 (Table 2). This might explain why no difference was found between respondents of the GKCMA and other communities with respect to receipt of tornado warnings.

Because of the aforementioned problem, selected communities were divided into two groups based on size. Communities with populations of 25,000 or less were considered one group and the remaining communities with more than 25,000 people were in another group. Four cities (Kansas City, Kansas, Gladstone, Missouri, Liberty, Missouri, and Jackson, Tennessee) belonged to the latter group, while the remaining 16 communities fell into the former group. It appears from Table 3 that 14% of respondents from larger communities did not receive a tornado warning prior to a tornado touchdown. The corresponding percentage for the respondents in smaller communities was slightly over eight. This means that the smaller communities had a relatively higher access to tornado warning than the larger communities. This is not surprising since many residents of Jackson, Tennessee were asleep when the tornado struck their city and thus they were not aware of the warnings. Those that were awakened by the sirens in Jackson stated that the tornado was upon them within minutes of the sirens going off. However, the six percentage point difference between respondents of larger and smaller communities is not enough for making the relationship statistically significant. Thus, contrary to the expectation, it appears that community size had no bearing on access to tornado warnings among the respondents of Kansas, Missouri, and Tennessee.

When respondents were regrouped on the basis of whether they were living in the urban or rural communities at the time of the tornado, a significant difference became evident between respondents of these two types of communities with respect to warning access. Table 3 clearly suggests that respondents of urban communities were more likely to a have tornado warning than respondents of rural communities. The chi-square is 11.284, which is highly significant. As is evident from Table 3, only nine respondents were drawn from four rural areas. This low number is the result of low population density and non-availability of household members at the time of the research team's visit to the area. It is worthwhile to mention that two unincorporated communities (Ringo, Kansas and Franklin, Kansas) were not included in the rural group. If these two communities had been included, the difference with respect to availability of tornado warning between urban and rural areas would be even higher than reported in Table 3.

Although not all rural communities are equipped with siren warning systems, rural communities outside of larger towns can often hear the sirens. This, however, is not always the case. The farther one lives from the source of sirens, the more difficult it is to hear them. A number of rural respondents cited wind direction and time of day as important in the ability to hear sirens. In Ringo, Kansas, residents said they only heard the sirens when the wind was blowing in the right direction. One resident in Franklin, Kansas, said that she did not hear the sirens from the nearby town of Arma, Kansas. Though many study communities can hear some type of siren, Neely Station, Tennessee, is not equipped with a siren warning system and respondents in this community were unable to hear sirens from nearby towns. Rural areas often rely on policemen to drive around with their squad car sirens turned on for the residents to hear. However, one respondent in Liberal, Missouri reported that it is difficult to know the difference between a tornado warning and a police emergency when the sheriff drives down the road with the siren blaring.

It was quite evident from the field survey that tornado warnings during the day were more successful in alerting the public. Communities without sirens relied on the television or radio to provide severe weather information. If a tornado strikes at night, people without sirens have no warning to seek shelter. Additionally, when a tornado occurs during the day, people are more apt to witness the oncoming tornado than if it occurs during the night. To test whether access to tornado warnings significantly differs by day and night, the responses of the survey participants are regrouped (Table 3). As noted previously, the tornado struck three communities of Tennessee (Jackson, Neely Station, and Lexington) at night. All the selected communities of Kansas and Missouri, in contrast, experienced tornados before sundown. As expected, nearly 95% of all respondents in Kansas and Missouri received tornado warnings as opposed to 71% in the case of respondents in Tennessee. This difference is highly significant.

As is evident from Table 3, warning receipt is also analyzed by seven selected variables. The table shows that middle and older-aged respondents, female, employed, and higher educated respondents were less likely to have been aware of the tornado warning than respondents of younger ages, male, unemployed, and less educated. The table further suggests that married and higher income respondents were more likely to be aware of the warning than unmarried, widowed, or divorced respondents, and those who earned less than $40,000 per year. But none of these differences is statistically significant (Table 3). The racial difference is the only one that becomes highly significant.

With the exception of two communities (Jackson and Neely Station) in Tennessee, other tornado-impacted communities selected in this study are primarily inhabited by caucasian Americans. In Jackson, the downtown area was hardest hit by the tornados. In addition to businesses, residential areas close to downtown were also devastated by the tornados. Most people that live in these areas are African-American. Most of the residents of Neely Station are also African-American. Two points must be mentioned in terms of racial difference found in this study with respect to access to tornado warnings. First, the racial difference may be inflated because of the timing of the issuance of tornado warnings. Second, the observed racial difference may seem inconsistent with the income variable. Most of the African-American respondents were poor and still income difference did appear as statistically significant. Two factors might explain this situation. Most of the communities selected in this study tended to be poorer and nearly 40% of the respondents were retired, students, disabled, or unemployed. They earn much less than the employed respondents. Thus, it was challenging to find a significant difference between household income and access to tornado warnings.

CONCLUSION

The purpose of this study was to examine how well tornado warnings worked on May 4, 2003, in tornado-affected communities of Kansas, Missouri, and Tennessee. Special attempts were made to investigate whether warnings differed by selected characteristics of the impacted communities and tornado survivors. Face-to-face interviews were conducted to collect relevant information from the respondents. This survey revealed that most respondents experienced damage from the tornado. This damage ranged widely from minor to severe. Similarly, the vast majority of respondents did receive a tornado warning (in some form) before the tornado actually hit their community. Although they received warnings from various sources, the most common source was sirens followed by television.

Almost all respondents who received warnings took shelter immediately. Warning awareness did increase shelter-seeking behavior which further strengthens the point that warning must be disseminated effectively. It appears that in the future respondents will be more likely to heed the warning and take cover. Warning lead-time ranged from 10-20 minutes in most communities. The respondents were generally satisfied with the warning systems. Among 10 variables considered, only three (rural versus urban residence, timing of issuance of tornado warnings, and race) appeared to be statistically significant determinants of access to tornado warnings.

Despite respondent satisfaction with the warning systems, there is a need for additional siren coverage for some communities, such as in the Badger Road area in southeast Kansas near Galena and in the Smithville, Missouri. As noted, Neely Station in Tennessee also has no siren system. This community needs to have a siren warning system installed. Residents of some communities such as Jackson, Tennessee, did not have basements. Therefore, it is necessary to have community shelters in these communities. This study further observed that respondents who experienced tornados at night did not receive warnings because they were asleep. It may be beneficial to educate residents on the use of NOAA weather radios. Such radios can warn people even when they are asleep and also when the electricity goes off due to severe storms. In the latter situation, television sets will be ineffective in disseminating actual tornado warnings. Only four respondents received warnings from weather radios. Although this study was not designed to examine performance of insurance companies, respondents and residents of tornado-impacted communities complained that insurance companies were not providing the services they were supposed to provide immediately after the disaster. This could be a topic for future disaster studies.

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Table 1. Selected characteristics of the respondents

Characteristic	Number	Percentage
Gender		
Male	75	58.14
Female	54	41.86
Marital Status		
Single	19	14.73
Married	84	65.12
Divorced	8	6.20
Widowed	18	13.95
Age (in years)		
<30	12	9.30
30-44	28	21.71
45-64	53	41.09
>64	36	27.90
Education		
Grade School	15	11.63
High School	53	41.09
Undergraduate and post-graduate	14	10.85
Employment		
Employed Full-time	59	45.74
Retired	39	30.23
Unemployed	8	6.20
Others	31	17.83
Income		
<$20,000	29	22.48
$20,000-39,999	33	25.58
$40,000-59,999	34	26.36
$60,000 and above	24	18.60
Not Answered	9	6.98

Table 2. May 4, 2003 Tornado-Impacted Communities in Kansas, Missouri, and Tennessee

Name of Community and State	Number of Death	Maximum F Intensity	Population (2000)	Time
Columbus, KS	1	F3	3,396	4:55 pm
Galena (Badger Road), KS	2	F3	3,287	4:55 pm
Girard, KS	1	F4	2,773	5:00 pm
Ringo, KS	1	F4	-	5:05 pm
Franklin, KS	1	F4	375	5:15 pm
Kansas City, KS	1	F4	146,866	4:26 pm
Carl Junction, MO	1	F3	5,294	5:16 pm
Liberal, MO	1	F2	779	5:30 pm
Stockton, MO	3	F3	1,960	5:55 pm
Pierce City, MO	7	F4	1,385	6:04 pm
Smithville, MO	1	F3	5,514	5:01 pm
Jackson, TN	2	F4	59,643	8:00 pm*
Neely Station (Denmark), TN9		F4	-	8:00 pm*
Aurrora, MO	0	F3	7,014	6:14 pm
Verona, MO	0	F3	714	6:10 pm
Gladstone, MO	0	F4	26,365	4:45 pm
Liberty, MO	0	F2	26,232	4:59 pm
Northmoreland, MO	0	F3	399	4:42 pm
Pleasant Vallet, MO	0	F4	3,321	4:55 pm
Lexington, TN	0	F3	7,393	8:10 pm*

*According to the respondents, the tornado hit their community at midnight.
Source: NWS (2003). 2000 population figures are taken from the U.S. Census Bureau's website.

Table 3. Tornado warnings by selected community and respondent characteristics

Characteristic	Received Tornado Warning Yes Number (%)	No Number (%)	Total Number (%)
Place of Residence 1			
GKCMA	38 (92.68)	3 (7.32)	41 (100.00)
Other Communities	77 (87.50)	11 (12.50)	88 (100.00)
χ^2=0.777 (d.f.=1; p=0.378)			
Place of Residence 2			
Population 25,000 or less	49 (85.96)	8 (14.04)	57 (100.00)
Population over 25,000	66 (91.67)	6 (8.33)	72 (100.00)
χ^2=1.069 (d.f.=1; p=0.310)			
Place of Residence 3			
Urban	110 (91.67)	10 (8.33)	120 (100.00)
Rural	5 (55.56)	4 (44.44)	9 (100.00)
χ^2=11.284 (d.f.=1; p=<0.001)			
Warning Issuance Time			
Day	93 (94.90)	5 (5.10)	98 (100.00)
Night	22 (70.97)	9 (29.03)	31 (100.00)
χ^2=13.939 (d.f.=1; p=<0.001)			
Age (in years)			
44 and below	36 (90.00)	4 (10.00)	40 (100.00)
45 and over	79 (88.76)	10 (11.24)	89 (100.00)
χ^2=0.044 (d.f.=1; p=0.835)			
Gender			
Male	67 (89.33)	8 (10.67)	75 (100.00)
Female	48 (88.89)	6 (11.11)	54 (100.00)
χ^2=0.006 (d.f.=1; p=0.936)			

Marital Status			
Married	75 (89.29)	9 (10.71)	84 (100.00)
Others	40 (88.89)	5 (11.11)	45 (100.00)
χ^2=0.005 (d.f.=1; p=0.945)			
Employment Status			
Employed	51 (86.44)	8 (13.36)	59 (100.00)
Others	64 (91.43)	6 (8.57)	70 (100.00)
χ^2=0.823 (d.f.=1; p=0.364)			
Education			
Up to High School	62 (91.18)	6 (8.82)	68 (100.00)
Beyond High School	53 (86.89)	8 (13.11)	61 (100.00)
χ^2=0.612 (d.f.=1; p=0.434)			
Annual Household Income			
Less than $40,000	54 (87.10)	8 (12.90)	62 (100.00)
$40,000 and over	52 (89.66)	6 (10.34)	58 (100.00)
χ^2=0.190 (d.f.=1; p=0.663)			
Race			
White Americans	100 (94.34)	6 (5.66)	106 (100.00)
African Americans	15 (65.52)	8 (34.78)	23 (100.00)
χ^2=16.567 (d.f.=1; p=<0.001)			

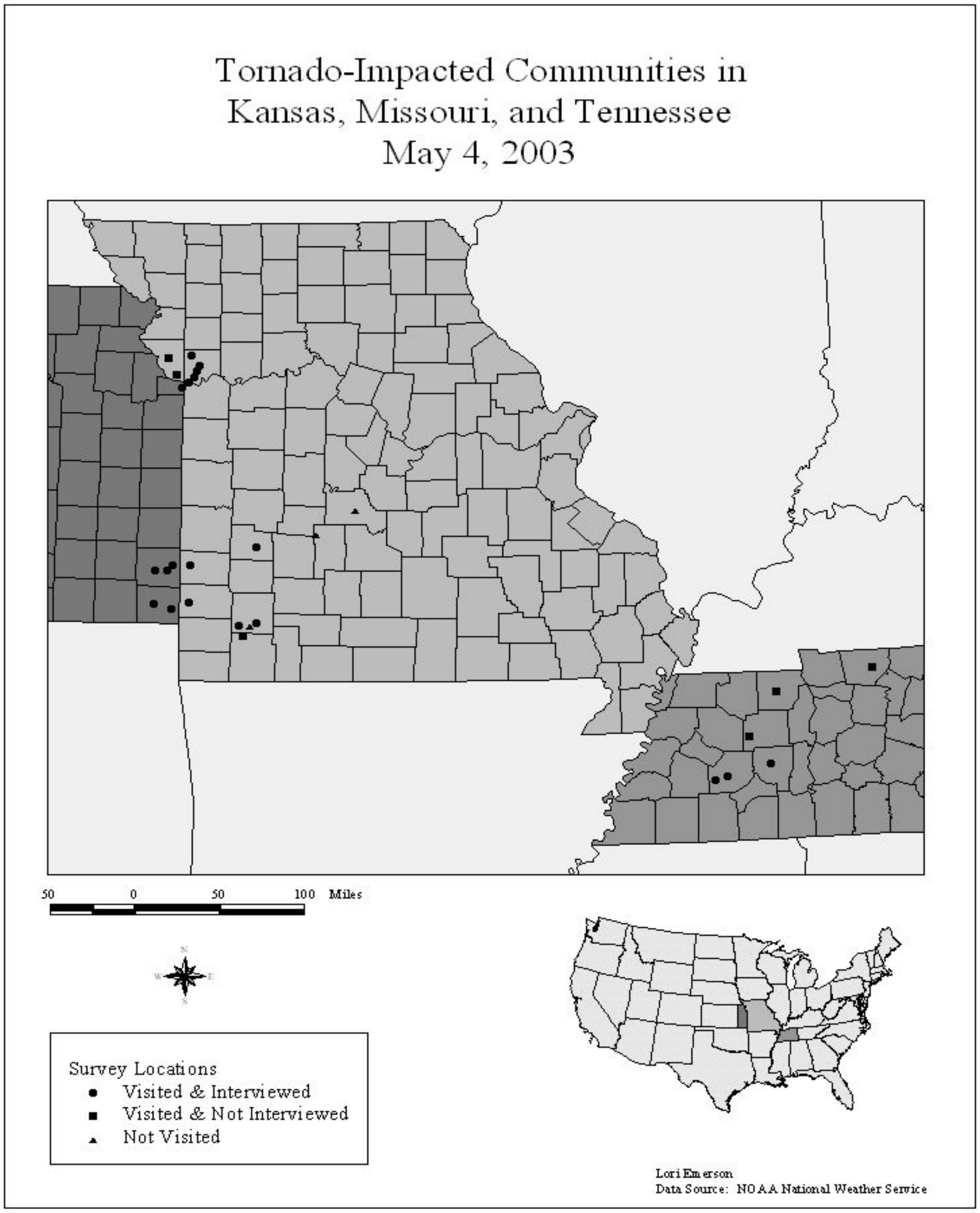

Figure 1. Tornado-Impacted Communities in Kansas, Missouri, and Tennessee, May 4, 2003.