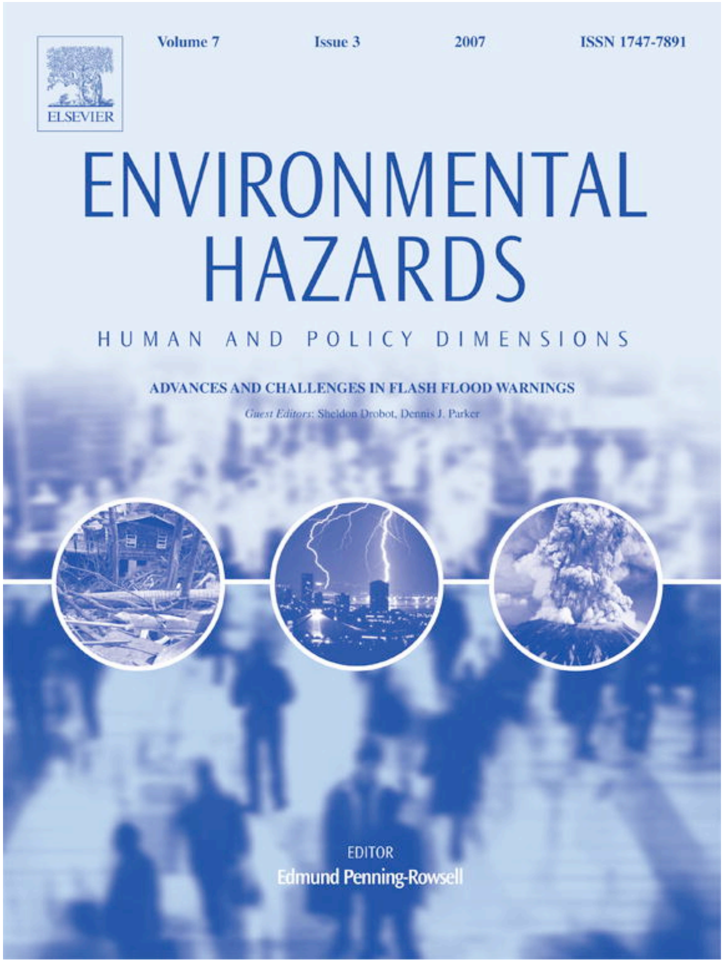
Volume 7
Issue 3
2007
ISSN 1747-7891
ELSEVIER
ENVIRONMENTAL HAZARDS
HUMAN AND POLICY DIMENSIONS
ADVANCES AND CHALLENGES IN FLASH FLOOD WARNINGS
Guest Editors: Sheldon Drobot, Dennis J. Parker
EDITOR
Edmund Penning-Rowsell

ELSEVIER

Environmental Hazards 7 (2007) 211–219

ENVIRONMENTAL HAZARDS

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Information sources for flash flood warnings in Denver, CO and Austin, TX

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Abstract

This research examines sources of information for flash floods in two large metropolitan areas, Denver, CO, and Austin, TX. Previous research has noted that information delivery systems for weather forecasts are geared toward the cultural majority and suggests that inadequate warnings are a primary contributor to deaths and injuries from hazards. This investigation used chi-square analysis to determine the prime warning source preferences and preferred time of day for receiving different media. Results indicate that successful warning messages need to be targeted toward specific sub-populations if the warning is to be received, understood, and responded to properly.

Keywords: Weather warnings; Weather information sources; Floods

1. Introduction

As loss of life and property from flooding increases in the United States (Downton and Pielke, 2001), the need to reduce the level of risk becomes critical. Loss reduction from flooding is dependent not only on adequate preparation and lead time, but also on effective warning dissemination and public response to the warning.

Previous research notes that information delivery systems for weather forecasts are inadequate or unreliable in many instances (Parker et al., 1995; Parker and Fordham, 1996) and highlights the importance of warning dissemination as well as response in a "successful" flood warning (Goulter and Myska, 1987). Studies indicate that warnings are geared toward the cultural majority and are less likely to reach those who are most vulnerable—the poor, the elderly and cultural minorities (Burton et al., 1987; Miletti, 1999; Perry et al., 1984; Lindell and Perry, 2004). Furthermore, Handmer (2000) notes that populations that are susceptible to flooding are often diverse which makes it difficult to tailor and deliver warning messages to ensure 100% coverage.

Balluz et al. (2000) and Noji (1997) suggest that inadequate warnings are a primary contributor to deaths and injuries from short-fuse disasters such as tornadoes. Additionally, earlier studies have demonstrated the importance of factors such as trust in government in influencing subsequent response to a warning (Lindell and Perry, 2004) and highlighted lack of credibility of government authorities, particularly where minorities are concerned (Perry et al., 1984).

To address these issues in the context of flash-floods, this paper evaluated the types of information sources used for

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doi:10.1016/j.envhaz.2007.07.001

flash floods, and determined the importance of differing times of day for preferred warning sources, critical information for emergency managers to ensure that the public at risk is receiving the intended warnings, a first step toward response to prevent loss of life and property.

2. Background

Earlier research indicated that public reliance on "official" warnings from traditional sources may be shifting to more private and informal sources (Penning-Rowsell et al., 1978; Baker, 1995; Dow and Cutter, 1998; Drabek, 2001). Whether people use new, previously unavailable, sources of information and what factors they take into consideration needs to be more clearly understood.

Studies undertaken by Dow and Cutter (1997, 1998) in the aftermath of 1994 Hurricanes Fran and Bertha in South Carolina indicate that earlier findings on warning response behavior do not account for the current context of warning responses. Specifically, they found that the perceptions of the public are affected by elements that did not exist 30 years ago, including information provided by the private sector such as The Weather Channel and a reduced reliance on top–down information from emergency managers (Dow and Cutter, 1998). Their study of "close calls" for these hurricanes found that official information is only one of many sources the public uses to make evacuation decisions. A "public" that once relied solely on the advice of emergency managers, now uses a variety of sources including The Weather Channel, the Internet, and sophisticated graphical images to make evacuation decisions (Baker, 1995; Dow and Cutter, 1998). In a 2002 Colorado wildfire study conducted by Benight et al. (2004), most of the respondents made use of a combination of sources of information on the fires. More than one source of information was used by over 75% of the study participants; 50% drew on three or more sources of information, primarily radio, Internet, phone, television, and the newspaper. Slightly over 35% used four or more sources for their information.

Ensuring that warning information sources are received becomes even more critical in short-fuse disasters such as flash floods. In a study conducted after the November 1998 flash flood in Arkansas City and Augusta, Kansas, survey results indicated that 58% of respondents were dissatisfied with the issuance of the flash flood warning for the event. Greater than 75% of the participants claimed to have had no flood warning or not to have received the warning in a timely manner to protect property (Paul, 1999). For the March 1997 tornadoes in Arkansas, Schmidlin and King (1997) found that government warnings on the television preceded the tornado by 18–32 min and 73% of their respondents had a television turned on. However, 61% of the respondents reported first becoming aware of the danger when they saw or heard the tornado. Legates and Biddle (1999) also indicated that in the April 1998 Oak Grove, Alabama tornado, 85% of their study respondents became aware of the tornadoes on television. McEntire's (2001) quick response study of the March, 2000 Fort Worth, TX tornado highlights how little time is involved from the initial official recognition of the tornado, issuance of a warning, and the event. In the 8 min between the time the rotation was spotted, a warning issued and emergency sirens deployed, and the tornado struck, 50 homes were damaged. This is a critical issue with short lead-time events where initial sighting or environmental cues may be the only warning the public receives.

Most of the more contemporary warning research has focused on disasters with longer lead times with short-fuse disasters receiving minimal attention. Warning systems for short-fuse events pose a different set of problems for forecasters, emergency managers, and the public at risk due to the limited lead time; increased attention to short lead-time warnings is critical (Dengler, 1998; Gruntfest and Handmer, 2000; Handmer, 2000, 2001; Penning-Rowsell et al., 2000). Although the aforementioned research demonstrates that the public is using more sources of warning information, studies have been few and far between. Additionally, little is known about how channels of information influence effective responses in short-fuse events.

New physical science knowledge does not automatically lead to improved responses; it is not enough to simply provide real-time information. The message must also be understood and used; as such, a successful warning, including the response, depends on both psychology and technology as risk perception is a complex process (Smith and Tobin, 1979; Parker and Hardy, 1979; Lindell and Whitney, 2000; Drottz-Sjöberg, 2000). The link between awareness and response is not necessarily direct. Successful warnings must incorporate risk perception in order for warnings to be meaningful to recipients and motivate risk acceptance and the adoption of risk reduction behavior.

3. Methods

This paper examines results from "The Warning Project", a National Science Foundation funded study examining geographic and psychological components of warnings in Denver, CO and Austin, TX.

3.1. Study locations

Denver, CO (pop. 554,636) and Austin, TX (pop. 656,562) were selected as survey sites for this study (US Census, 2000). Both are rapidly growing urban areas in the United States. In Austin, floods are the leading cause of weather related deaths (Austin City Connection, 2002). Although Denver has experienced fewer flood events, it often experiences severe thunderstorms during the spring and summer months which have resulted in flash floods. (NWS, 2007).

3.2. Survey development

Two survey instruments were developed to assess perceptions of short-fuse weather hazards in Denver and in Austin. The questionnaires were developed in 2003, and the questionnaire drafts were reviewed by a select advisory committee made up of officials involved in floodplain management and weather warnings from Denver and Austin. The questionnaires were tailored for the risks and local hazards and geography for each city. The advisors served as a "local knowledge" base to enhance the likelihood that the most critical "local" aspects were incorporated in the study.

Questions were designed to assess the use of new warning information sources, new sources of technology, experience with false alarms, attitudes toward government, previous experience with the hazard, physical understanding of the potential hazards, physical limitations, demographic characteristics, trauma history, and perceptions of coping. The present study focused specifically on the sources of information used by participants in the event of flash flooding.

In addition to the general survey questions, two brief flash flood scenarios were also included based on actual severe weather events in both Denver and Austin followed by warning behavior questions. Two tornado scenarios were also included in the Austin survey. The scenarios were developed to provide a realistic warning context for respondents facing imminent severe weather conditions: one was based on being at home and the other while driving. Particular localized scenarios were written to elicit respondents' perceptions of environmental cues such as 6 in of water on the road, the issuance of official warnings, and how their perceptions differed if they were at home or driving. The survey and pre-survey letter were translated into Spanish by two different people fluent in Mexican Spanish and Spanish spoken in Spain, and linguistic consensus was reached to ensure cultural validity.

3.3. Sampling methodology

The survey procedure was conducted based on the Dillman (2000) method for mail and Internet questionnaires. The 90 question survey of 16 pages had seven parts: (1) your thoughts about flash floods; (2) imagine yourself in a flash flood situation; (3) your experiences with flash floods; (4) imagine yourself in a tornado situation (only in Austin, because Denver has a lower tornado risk); (5) your weather information sources; (6) your experiences with trauma; and (7) about you and your family. The survey is available in electronic format from the first author for follow-up research on other hazards or in other cities.

The Denver part of the two city study was conducted first. The sample was drawn from floodplain addresses developed by the Urban Drainage and Flood Control District in Denver. A total of 3000 households was selected. In September 2004, 1500 pre-survey letters were sent to 1500 randomly selected residences in the Denver sample to inform them that a survey would follow shortly. Within two days of mailing the letter, 1500 surveys were sent out. A reminder/thank you postcard was sent approximately two weeks after the initial mailing. Two weeks later 195 completed surveys were returned. A second mailing of 1375 reminder postcards was mailed in November 2004. A second full questionnaire packet was sent to those who did not respond. Then another round of 610 surveys was mailed. Rather than sending out a third mailing, a new randomly selected subset of the original set of addresses not utilized in the first random sample was selected for a final mailing. In December of 2004, 1300 pre-survey letters were mailed, followed by 1300 surveys two days later. The final number of returned surveys for Denver was 415 for a response rate of 14.8%.

A flood plain list was also obtained through the Watershed Protection and Development Review Agency in Austin. In Austin the same methodology (Dillman, 2000) was utilized with pre-post cards followed by a mass mailing. An initial 1500 randomly selected addresses were sent surveys. A second mailing was sent to those who did not return the first survey. A total of 519 surveys were sent back to us from Austin residents for a return rate of 34.6%.

4. Survey results

4.1. Which best describes the information source you consider the most important?

In both Denver and Austin, local TV stations are considered the most important source for obtaining weather information, with cell phones and the weather bug rarely used as a primary source in either city (Fig. 1). Additionally, the internet is not the most important source of weather information for many people. Comparing the two cities, a chi-square[1] test confirms that survey participants differ in their response to this question ($\chi^2 = 69.95$; p-value < 0.001). Denver residents rely more on environmental cues and local radio stations, whereas Austin residents are more likely to favor the Weather Channel and NOAA Weather Radio.

In assessing the most important source for weather information, gender effects are only apparent in Denver ($\chi^2 = 20.33$; p-value $= 0.009$), where males are more likely to view environmental cues (28% versus 20%) or radio stations (26% versus 17%) as the key source (Table 1). In comparison, females are more likely to view local TV as the

[1]Chi-square tests are used in this paper to assess the hypothesis of no association between the question of interest and the demographic variables. Traditionally, p-values less than or equal to 0.05 provide strong evidence that there is a difference.

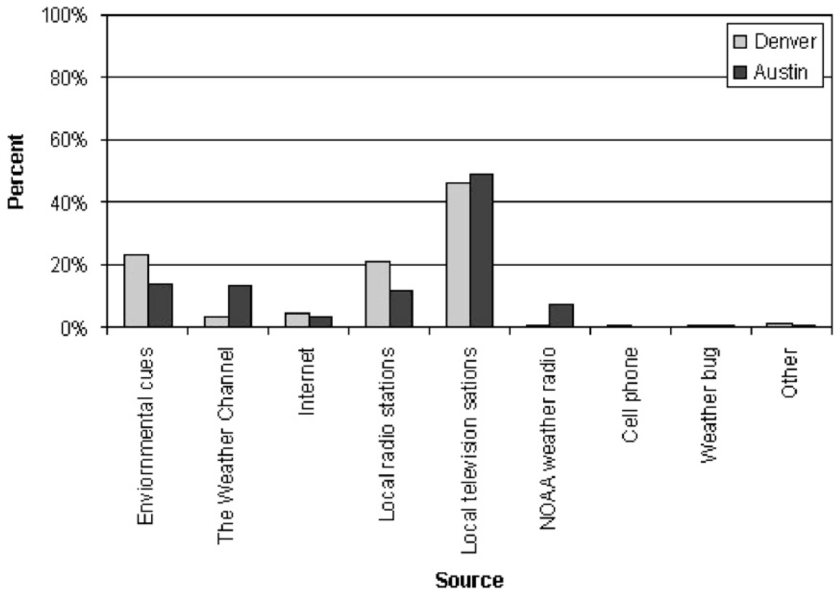

Fig. 1. Response to the question, "Which best describes the information source you consider the most important?"

Table 1
Percentage of respondents answering "Which best describes the information source you consider the most important?" stratified by gender, education, age, and ethnicity

Denver	Gender		Education[a]		Age group			Ethnicity	
Source	F	M	HS	Coll	18–35	36–65	66+	W	H
Environmental cues	20	28	19	24	21	28	15	23	17
The Weather Channel	5	1	6	3	6	2	2	2	25
Internet	6	2	0	5	9	4	0	5	0
Local radio	17	26	22	21	19	18	30	22	21
Local TV	52	38	51	45	42	44	52	45	38
NOAA Weather Radio	0	1	1	1	1	1	0	1	0
Cell phone	0	1	0	0	0	0	0	0	0
Weather bug	0	1	0	1	1	0	1	1	0
Other	0	2	0	1	0	2	0	1	0
Chi-square	**20.33**		**8.46**		**28.97**			**41.25**	
p-Value	**0.01**		**0.39**		**0.02**			**0.00**	
Environmental cues	14	16	5	16	13	18	7	16	7
The Weather Channel	15	10	22	10	14	10	17	10	19
Internet	5	2	1	4	11	3	0	4	3
Local radio	11	12	10	11	9	13	11	13	4
Local TV	47	51	54	48	51	47	53	46	59
NOAA Weather Radio	7	7	5	8	1	7	13	8	7
Cell phone	0	0	0	0	0	0	0	0	0
Weather bug	1	1	1	1	1	1	0	1	1
Other	0	2	1	1	0	1	0	1	0
Chi-square	**10.53**		**16.24**		**40.95**			**14.03**	
p-Value	**0.23**		**0.04**		**0.00**			**0.05**	

Chi-square and associated *p*-values are listed at the bottom of each column, and this test was for all sources combined. *p*-Values less than 0.05 are considered statistically significant.

[a]"HS" equals that the respondent has at most a high-school education; "Coll" means that the respondent has taken some college courses at a minimum.

primary source for weather information (52% versus 38%). In Austin, there are no significant differences in the most important information source based on gender.

Although education has no significant effect on how Denver respondents answered the question on the most important source for weather information, there is evidence to support an education effect in Austin ($\chi^2 = 16.24$; *p*-value = 0.04; Table 1). Specifically, respondents with at least some college education were more likely to use environmental cues as the main information source (16% versus 5%) and those with a maximum high-school education were more likely to list the Weather Channel (22% versus 10%) and local TV (54% versus 48%) as their key information source.

In contrast to the above two demographic variables, age differences are apparent in both cities in response to the question of most important source of information (Table 1). In Denver, the 36–65 age group relies more on environmental cues than the other age groups, and there is some evidence to suggest that the younger the age group, the more important the internet is, although the overall percentages remain small. There also appears to be more reliance on local TV and local radio in the 66+ age group in comparison with the other age groups. In Austin, the 18–35 age group is more likely to use the internet as its main information source than the other two age groups. On the other hand, the 66+ age group is more likely to use NOAA Weather Radio than the other two age groups.

There appears to be a large ethnicity effect in Denver ($\chi^2 = 41.25$; *p*-value$<$0.001; Table 1) and a smaller one in Austin ($\chi^2 = 14.03$; *p*-value = 0.05), although sample sizes for Hispanics were low. In Denver, whites are more likely to use environmental cues (23% versus 17%) and local TV (45% versus 38%), with Hispanics more likely to use The Weather Channel (25% versus 2%). In comparison, whites in Austin are more likely to rely on environmental cues (16% versus 7%) and local radio (13% versus 4%), and Hispanics are more likely to use local TV (59% versus 46%) and The Weather Channel (19% versus 10%).

4.2. What are all your sources of weather information?

In addition to asking about their most important source for obtaining weather information, respondents were also asked about all sources of weather information they use. The results parallel the previous question, with local TV used by the most people, regardless of city (Fig. 2). Local radio is the second most often used source of weather information, with internet being used by about 4 in 10 people. The Weather Channel and NOAA Weather Radio are used far more often in Austin than in Denver. Cell phones are not a source of weather information for the vast majority of respondents.

Gender effects are once again apparent in the Denver response to this question (Table 2), with Denver females more likely to use local TV (93% versus 87%; $\chi^2 = 4.37$; p-value $= 0.037$). As in the previous question regarding most important source of information, there are no significant differences based on gender in Austin.

Although education did not differentiate the most important weather information source in Denver, there is considerable evidence to suggest that there are education effects in all sources of weather information. For example, those with at least some college education were significantly more likely to use environmental cues (85% versus 61%; $\chi^2 = 23.83$; p-value<0.001) and the internet (41% versus 14%; $\chi^2 = 19.51$; p-value<0.001). In Austin, those with at least some college education were more likely to use environmental cues (83% versus 48%; $\chi^2 = 49.91$; p-value<0.001) and the internet (50% versus 15%; $\chi^2 = 38.21$; p-value<0.001), and those with a maximum high-school education level were more likely to use the Weather Channel (80% versus 64%; $\chi^2 = 8.58$; p-value $= 0.003$).

Both cities also show age-related differences in answering which sources they utilize for obtaining weather information. In Denver, the 18–35 and 36–65 groups are more likely to use environmental cues than the 66+ age group (87% and 87% versus 61%; $\chi^2 = 31.34$; p-value <0.001), and the 18–35 group is far more likely to use the internet than the other two age groups (70% versus 35% and 8%; $\chi^2 = 74.58$; p-value <0.001). The 18–35 age group is also more likely to use Weather Bug. There is a statistically significant difference in local TV use, with the 66+ group being higher (96% versus 85% and 90%; $\chi^2 = 6.34$; p-value $= 0.042$), but TV use remains high in all groups. In Austin, age differences

Table 2
Percentage of respondents answering "What are all your sources of weather information?" stratified by gender, education, age, and ethnicity

Denver	Gender		Education[a]		Age group			Ethnicity	
Source	F	M	HS	Coll	18–35	36–65	66+	W	H
Environmental cues	80	81	**61**	**85**	**87**	**87**	**61**	**83**	**57**
The Weather Channel	45	46	52	44	45	47	41	**42**	**68**
Internet	37	34	**14**	**41**	**70**	**35**	**8**	36	32
Local radio	72	78	79	73	70	78	71	75	75
Local TV	**93**	**87**	95	89	**85**	**90**	**96**	100	100
NOAA Weather Radio	8	14	10	11	9	14	5	10	21
Cell phone	1	1	0	2	1	1	1	1	0
Weather bug	9	8	8	8	**16**	**6**	**5**	**6**	**21**
Environmental cues	78	73	**48**	**83**	**84**	**78**	**64**	**83**	**46**
The Weather Channel	69	65	**80**	**64**	62	66	77	**64**	**82**
Internet	44	41	**15**	**50**	**70**	**44**	**15**	**48**	**30**
Local radio	73	78	70	76	**83**	**76**	**67**	74	75
Local TV	91	93	94	91	**84**	**94**	**94**	90	96
NOAA Weather Radio	23	27	21	26	**14**	**25**	**33**	26	21
Cell phone	3	5	6	3	6	3	4	3	6
Weather bug	13	15	11	14	**13**	**17**	**5**	14	17

Bold cells indicate a significant difference for the specific source (at $\alpha = 0.05$). See text for more details.

[a] "HS" equals that the respondent has at most a high-school education; "Coll" means that the respondent has taken some college courses at a minimum.

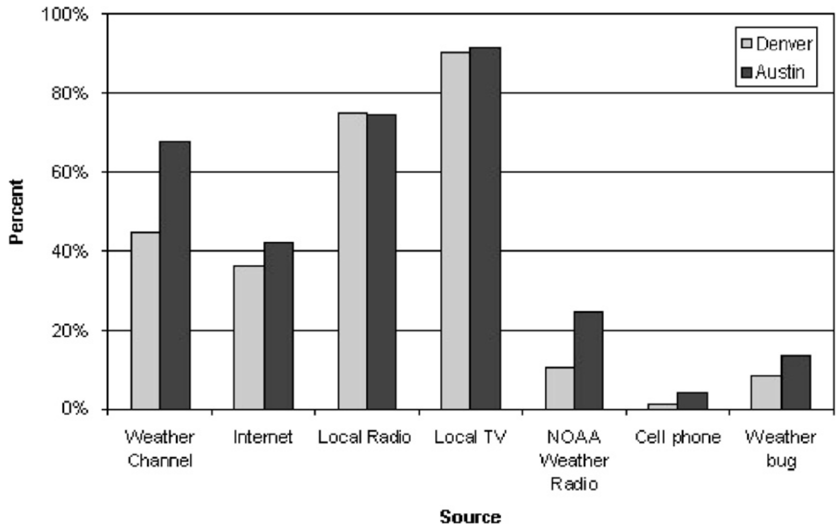

Fig. 2. Response to the question, "What are all the places that you get your weather information?"

are apparent for nearly all of the information sources. The 18–35 group is more likely to use environmental cues, the internet, and local radio (Table 2). As with Denver, the 66+ age group is more likely to use local TV (94% versus 84% and 94%), but the percentage use is high across all age groups.

In Denver, there are ethnic differences related to environmental cues, The Weather Channel, and the Weather Bug (Table 2). Whites are more likely to use environmental cues (83% versus 57%), with Hispanics more likely to use The Weather Channel (68% versus 42%) and the Weather Bug (21% versus 6%). In Austin, ethnicity mirrors the education findings. Whites are more likely to use environmental cues (83% versus 46%), as well as the internet (48% versus 30%). In comparison, Hispanics are more likely to rely on The Weather Channel (82% versus 64%).

4.3. *The best way for officials to warn you about a flash flood?*

The final question asked respondents to comment on the best ways for officials to communicate a flash flood warning at 2:30 am, 11:00 am, and 5:00 pm. In this case, the respondents could select as many warning sources as they wanted. Denver respondents preferred sirens at all three times of the day, with roughly 3 in 4 noting that sirens were a good way to warn them (Fig. 3a). In Austin, the preferred method varied by time of day; at 2:30 am sirens were preferred more than any other method, with local radio the most favored at 11:00 am, and local television the top choice at 5:00 pm (Fig. 3b). The preference for sirens is a particularly striking result. Denver currently has 73 outdoor warning sirens that are activated for any type of

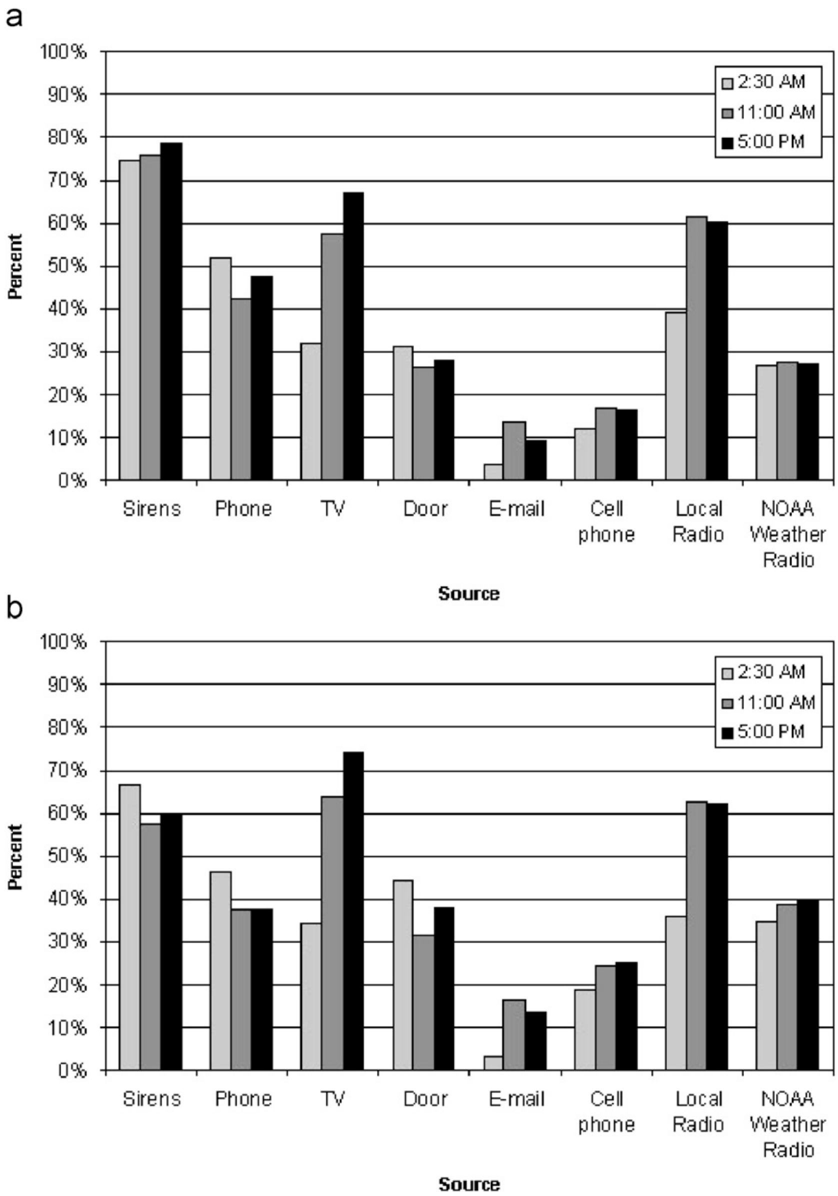

Fig. 3. Response to the question, "The best way for officials to warn you about a flash flood?" where respondents could select all that apply: (a) Denver and (b) Austin.

hazard deemed a serious threat. In comparison, Austin does not have a siren system, but the respondents would clearly prefer such a warning method—even at other times of the day, more than 50% of Austin respondents felt that sirens were good ways to disseminate a warning.

Within both city samples, there is again evidence to conclude gender, education, and age differences in respondent's preferences for receiving warning information. Females tend to prefer sirens more than males in both cities (Tables 3 and 4), and there is some evidence that Denver females prefer calls by phone in the middle of the night as well as scrolling along the TV bottom at 5:00 pm. In comparison, Denver males are more likely to want local radio or NOAA Weather Radio at 2:30 am. In Austin, females are more likely to want officials to come to the door (except at 2:30 am). There is a possibility that Austin males prefer e-mail at 2:30 am, but the sample sizes are too small to draw any realistic conclusion.

In Denver, those with a maximum of a high-school education appear to prefer officials coming to their door at 11:00 am and cell phone calls at 2:30 am, while those with at least some college education are apt to prefer e-mail at 11:00 am (Table 3). Overall, though, there is little evidence to conclude that education differences play a significant role in preferences for warning information. In Austin, the only education-related effect appears to be e-mail, with those having at least some college preferring e-mail at 11:00 am and 5:00 pm (Table 4).

In both Denver (Table 3) and Austin (Table 4), there is considerable evidence of age-related preferences in warning sources. In Denver, the 66+ age group is more likely to prefer sirens (significant at 2:30 am and 11:00 am) and having officials come to their door (all times significant), and less likely to want radio warnings (all times significant). The 18–35 age group prefers e-mail more than the other two groups at 11:00 am, is more likely to want a cell phone warning at any time of the day, and prefers NOAA Weather Radio at all times of the day. In Austin, the 66+ age group is more likely to want phone calls at 2:30 am and 11:00 am, as well as having officials to come to their door (all times significant). As with Denver, the 18–35 age group

Table 3
Percentage of Denver respondents answering "What are the best way for officials to warn you about a flash flood" stratified by gender, education, age, and ethnicity

Denver	Gender		Education[a]		Age group			Ethnicity	
Source	F	M	HS	Coll	18–35	36–65	66+	W	H
Sirens—2:30 am	**79**	**68**	72	75	**63**	**74**	**84**	73	79
Sirens—11:00 am	78	72	72	76	**71**	**73**	**85**	75	82
Sirens—5:00 pm	81	75	76	78	79	75	84	77	82
Phone—2:30 am	**57**	**44**	49	52	41	55	52	52	46
Phone—11:00 am	46	38	43	42	36	43	46	44	36
Phone—5:00 pm	51	42	50	46	38	48	52	48	32
TV—2:30 am	31	32	37	30	33	29	36	**28**	**50**
TV—11:00 am	59	54	62	56	60	56	57	56	61
TV—5:00 pm	**71**	**62**	68	67	65	68	66	67	68
Door—2:30 am	34	27	38	30	**19**	**30**	**46**	32	21
Door—11:00 am	27	25	**37**	**24**	**17**	**24**	**41**	28	18
Door—5:00 pm	28	28	37	26	**17**	**27**	**40**	29	25
E-mail—2:30 am	2	6	3	4	6	5	0	3	0
E-mail—11:00 am	15	12	**7**	**16**	**24**	**15**	**2**	14	7
E-mail—5:00 pm	10	8	8	10	13	11	3	8	7
Cell—2:30 am	11	14	**20**	**11**	**20**	**12**	**5**	12	14
Cell—11:00 am	17	17	18	17	**27**	**18**	**5**	18	11
Cell—5:00 pm	15	19	18	16	**27**	**18**	**4**	17	14
Radio—2:30 am	**35**	**46**	41	39	**47**	**41**	**29**	37	46
Radio—11:00 am	60	63	67	60	**69**	**63**	**49**	60	61
Radio—5:00 pm	59	63	61	61	**66**	**64**	**48**	60	64
NOAA W× Radio—2:30 am	**23**	**32**	25	27	**40**	**25**	**18**	25	36
NOAA W× Radio—11:00 am	24	32	29	27	**38**	**26**	**20**	26	39
NOAA W× Radio—5:00 pm	24	31	25	27	**37**	**27**	**18**	26	39

Bold cells indicate a significant difference for the specific source (at $\alpha = 0.05$). See text for more details.

[a]"HS" equals that the respondent has at most a high-school education; "Coll" means that the respondent has taken some college courses at a minimum.

Table 4
Percentage of Austin respondents answering "What are the best way for officials to warn you about a flash flood" stratified by gender, education, age, and ethnicity

Austin	Gender		Education[a]		Age group			Ethnicity	
Source	F	M	HS	Coll	18–35	36–65	66+	W	H
Sirens—2:30 am	**71**	**61**	65	67	63	69	65	67	62
Sirens—11:00 am	**62**	**51**	49	59	34	35	35	59	53
Sirens—5:00 pm	**63**	**53**	54	61	49	62	65	60	56
Phone—2:30 am	46	48	46	47	**37**	**46**	**56**	46	46
Phone—11:00 am	41	34	36	38	**32**	**36**	**47**	37	40
Phone—5:00 pm	41	33	33	39	34	35	45	38	33
TV—2:30 am	36	31	39	33	43	33	27	31	39
TV—11:00 am	65	61	64	63	67	61	66	61	64
TV—5:00 pm	76	71	74	74	73	70	82	73	72
Door—2:30 am	46	43	47	44	**27**	**48**	**54**	45	44
Door—11:00 am	**37**	**23**	29	31	**16**	**31**	**46**	31	25
Door—5:00 pm	**43**	**29**	38	37	**24**	**38**	**47**	36	38
E-mail—2:30 am	**5**	**1**	1	4	**8**	**2**	**2**	3	1
E-mail—11:00 am	18	14	**5**	**19**	**32**	**15**	**5**	19	7
E-mail—5:00 pm	15	12	**4**	**16**	**23**	**14**	**5**	16	5
Cell—2:30 am	18	21	20	19	**32**	**19**	**10**	19	18
Cell—11:00 am	24	27	23	25	**35**	**25**	**16**	25	20
Cell—5:00 pm	24	28	20	26	**34**	**26**	**15**	26	19
Radio—2:30 am	36	38	37	36	43	36	31	34	39
Radio—11:00 am	60	67	55	64	69	63	56	64	55
Radio—5:00 pm	61	64	54	64	**70**	**64**	**50**	63	59
NOAA W× Radio—2:30 am	36	34	39	35	100	100	100	36	33
NOAA W× Radio—11:00 am	39	39	38	40	33	39	44	40	36
NOAA W× Radio—5:00 pm	39	40	38	40	35	39	45	40	40

Bold cells indicate a significant difference for the specific source (at $\alpha = 0.05$). See text for more details.

[a]"HS" equals that the respondent has at most a high-school education; "Coll" means that the respondent has taken some college courses at a minimum.

in Austin is more likely to prefer e-mail and cell phone warnings (in Austin, all times significant). Finally, there is some evidence to suggest that the 18–35 group prefers radio at 5:00 pm more than the other groups.

For warning preferences, there is little evidence to conclude much in the way of ethnic differences. In Denver, the only significant difference is for scrolling on the bottom of the TV at 2:30 am, where Hispanics are more likely than whites to request this (50% versus 28%; Table 3). As with the previous question, ethnicity differences mirror education effects in Austin (Table 3). Whites prefer e-mail warnings more than Hispanics at 11:00 am (19% versus 7%) and 5:00 pm (16% versus 5%), but there are no other significant differences.

5. Discussion

The findings that age, education, and ethnicity affect warning information sources and preferences are particularly relevant when considering the spatial distribution of populations with these characteristics in each city. For example, warning messages tailored to a particular demographic characteristic, such as ethnicity, may be effective in some parts of a city but fail to penetrate others in the presence of strong demographic spatial organization.

It is clear that any warning messages tailored toward particular demographics should also be geographically targeted at sub-city spatial scales to best reach the intended audience. Thus, the major findings of this research include:

1. Television is by far the primary source for obtaining general weather information. Newer technologies, including the internet and cell phones, are used by fewer than 1 in 10 individuals as a primary weather information source. This highlights findings from ''Falling Through the Net: Defining the Digital Divide'' which concludes that the divide among the computer internet access ''haves'' and ''have-nots'' continues to grow particularly among Blacks, Hispanics and other minorities as well as seniors, the unemployed, single-parent (especially female-headed) households, those with lower levels of education, and those residing in urban areas or especially rural areas (NTIA 1999).

2. In addition to being the primary weather information source, television is used more than any other medium as a primary or secondary weather information source. It is important, however, to ensure that local television, not just satellite television, is accessible in the warned area if this is to be the authoritative source for warnings. (Zielinski-Gutierrez and Hayden, 2006). Although the internet, used by about 4 in 10 people, is becoming an important weather information source, the goal of any warning is to reach 100% of the population.

3. Residents in both cities still prefer traditional sources for weather warnings (e.g., sirens, TV) more than newer technologies (e.g., e-mail, cell phone). This is a particularly important finding for the Austin region where there are no sirens currently employed and suggests further research is necessary to determine if this finding pertains to all residents, not just those living in flood prone areas.

4. In general, there are significant differences between the responses from Denver and Austin. This raises the question as to whether these results are generalizable beyond Austin and Denver, but more importantly, highlights that warning officials may need to conduct site-specific surveys to best determine how their populations prefer to be warned based on differing demographic and cultural factors. Based on low internet preferences, this also points to the importance of employing surveys that are not solely internet-based to ensure that diverse populations are reached and their voices heard.

5. In examining demographic differences, there is considerable evidence for age-specific effects. The younger age group was far more likely to favor new technologies (internet, cell phone) for obtaining weather information, and less likely to favor traditional schemes (e.g., television, officials coming to their door). Nonetheless, television usage remained high. Although the newer technologies may become more important in the coming years, (NTIA, 1999) it is not necessarily the case that internet and cell phones will replace televisions nor be widespread in usage in home settings where it may be critical to receive weather warnings; instead, we conjecture that future populations may be using more varied sources for obtaining weather information. This provides warning officials with more opportunities to reach people with educational training campaigns, but it also may increase the complexity of issuing warnings to ensure that they reach 100% of the population because of the variety of information sources being used. This complexity is also underscored in our study by gender, education, and ethnicity effects. Females tend to prefer sirens more than males, those with some college education tend to prefer newer technologies more than those with a maximum of high-school level education, whites tend to use environmental cues more than Hispanics, and Hispanics tend to use The Weather Channel more than whites.

6. Conclusions

Based on earlier research indicating that public reliance on ''official'' warnings from traditional sources may be shifting to more private and informal sources, this paper examined the primary and secondary sources that Austin, TX, and Denver, CO residents use to obtain weather information, as well as all sources for obtaining weather warnings. In summary, the preferences expressed by the participants for the types of sources used for flash flood warnings and the importance of differing times of day for preferred warning sources, provide critical information for emergency managers to ensure that the public at risk is receiving the intended warnings. These findings highlight the importance of targeting warnings to distinctive segments of the public through diverse media and could inform emergency management and weather service policy on dissemination of warnings.

References

Austin City Connection, 2002. Austin Residents Still Not Recovered After November Floods 〈http://www.redcross.org/news/ds/floods020226austion.html〉.

Baker, E.J., 1995. Public response to hurricane probability forecasts. Professional Geographer 47, 137–147.

Balluz, L., Schieve, L., Holmes, T., Kiezak, S., Malilay, J., 2000. Predictors for people's response to a tornado warning: Arkansas, 1 March 1997. Disasters 24 (1), 71–77.

Benight, C., Gruntfest, E., Sparks, K., 2004. Colorado wildfires 2002. Natural Hazards Center Quick Response program Report No. QR167, Natural Hazards Center, Boulder, CO. 〈http://www.colorado.edu/hazards/research/qr/qr167/qr167.html〉.

Burton, I., Kates, R.W., White, G.F., 1978. The Environment as Hazard. Oxford University Press, New York.

Dengler, L., 1998. Strategic implementation plan for tsunami mitigation projects, approved by the Mitigation Subcommittee of the National Tsunami Hazard Mitigation Program, April 14, 1998. Technical Report NOAA Tech. Memo. ERL PMEL-113 (PB99-115552), NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 〈http://www.pmel.noaa.gov/pubs/PDF/deng2030/deng2030.pdf〉.

Dillman, D.A., 2000. Mail and Internet Surveys: the Tailored Method. Wiley, New York.

Dow, K., Cutter, S.L., 1997. Repeat response to hurricane evacuation orders. Natural Hazards Center Quick Response Program Report No. QR101, Natural Hazards Center, Boulder, CO. 〈http://www.colorado.edu/hazards/research/qr/qr101/qr101.html〉.

Dow, K., Cutter, S.L., 1998. Crying wolf: Repeat responses to hurricane evacuation orders. Coastal Management 26 (4), 237–252.

Downton, M.W., Pielke Jr., R.A., 2001. Discretion without accountability: Politics, flood damage and climate. Natural Hazards Review 2 (4), 157–166.

Drabek, T.E., 2001. Disaster warning and evacuation responses by private business employees. Disasters 25 (1), 76–94.

Drottz-Sjöberg, B.M., 2000. Exposure to risk and trust in information: implications for the credibility of risk communication. Australasian Journal of Disaster and Trauma Studies 2. 〈http://trauma.massey.ac.nz/issues/2000-2/drottz.htm〉.

Goulter, I.C., Myska, N.M., 1987. The Human Component in Flood Warning and Response System. GeoJournal 15, 297–305.

Gruntfest, E., Handmer, J., 2000. Dealing with flash floods, contemporary issues and future possibilities. In: Gruntfest, E., Handmer, J. (Eds.), Coping With Flash Floods. Kluwer Press, Dordrecht, The Netherlands, pp. 3–10.

Handmer, J., 2000. Are flood warnings futile? Risk communication in emergencies. Australasian Journal of Disaster and Trauma Studies 2. 〈http://trauma.massey.ac.nz/issues/2000-2/handmer.htm〉.

Handmer, J., 2001. Improving flood warnings in Europe: A research and policy agenda. Environmental Hazards 3, 19–28.

Legates, D.R., Biddle, M.D., 1999. Warning response and risk behavior in the Oak Grove—Birmingham, Alabama tornado of April 8, 1998. Natural Hazards Center Quick Response Program Report No. QR116, Natural Hazards Center, Boulder, CO. 〈http://www.colorado.edu/hazards/research/qr/qr116/qr116.html〉.

Lindell, M.K., Whitney, D.J., 2000. Correlates of household seismic hazard adjustment adoption. Risk Analysis 20 (1), 13–26.

Lindell, M.K., Perry, R.W., 2004. Communicating Environmental Risk in Multiethnic Communities. Sage, Thousand Oaks, CA.

Miletti, D., 1999. Disasters by Design: A Reassessment of Natural Hazards in the United States. Joseph Henry, Washington, DC.

McEntire, D.A., 2001. Multi-organizational coordination during the response to the March 28, 2000, Fort Worth tornado: an assessment of constraining and contributing factors. Natural Hazards Center Quick Response Program Report No. QR143, Natural Hazards Center, Boulder, CO. 〈http://www.colorado.edu/hazards/research/qr/qr143/qr143.html〉.

National Telecommunications and Information Administration. 1999. "Falling Through the Net: Defining the Digital Divide" Accessed April 2007 Available: 〈http://www.ntia.doc.gov/NTIAHOME/FTTN99/contents.html〉.

National Weather Service. 2007. Accessed: April 2007. Available: 〈http://www.crh.noaa.gov/bou/awebphp/Flash_Flood_Mountains.php〉.

Noji, E.K. (Ed.), 1997. The Public Health Consequences of Disasters. Oxford University Press, New York, NY.

Parker, D.J., Hardy, D.M., 1979. Natural hazards evaluation, perception and adjustment. Geography 64 (4), 307–316.

Parker, D., Fordham, M., 1996. An evaluation of flood forecasting, warning and response systems in the European union. Water Resources Management 10, 279–302.

Parker, D., Fordham, M., Tunstall, S., Ketteridge, A., 1995. Flood warning systems under stress in the United Kingdom. Disaster Prevention and Management 4 (3), 32–42.

Paul, B.K., 1999. Flash flooding in Kansas: a study of emergency response and victim's perception. Natural Hazards Center Quick Response Program Report No. QR118, Natural Hazards Center, Boulder, CO. 〈http://www.colorado.edu/hazards/qr/qr118.html〉.

Penning-Rowsell, E.C., Chatterton, J.B., Parker, D.J., 1978. The effect of flood warning on flood damage reduction. Report from Middlesex Polytechnic Flood Hazard Research, Project for Central Water Planning Unit. Enfield, Middlesex, UK.

Penning-Rowsell, E.C., Tunstall, S.M., Tapsell, S.M., Parker, D.J., 2000. The benefits of flood warnings: real but elusive, and politically significant. Journal of the Institution of Water and Environmental Management 14 (1), 7–14.

Perry, RW., Greene, M., Mushcatel, A., 1984. American Minority Citizens in Disaster 2 (2), 327–329.

Schmidlin, T.W., King, P.S., 1997. Risk factors for death in the March 1, 1997 Arkansas tornadoes. Natural Hazards Center Quick Response Program Report No. QR98, Natural Hazards Center, Boulder, CO. 〈http://www.colorado.edu/hazards/research/qr/qr98.html〉.

Smith, K., Tobin, G.A., 1979. Human Adjustment to the Flood Hazard. Longman Group Limited, London.

United States Census Bureau. 2000. Available: http://www.census.gov. Accessed: January 2007.

Zielinski-Gutierrez, E.C., Hayden, M.H., 2006. A model for defining West Nile virus risk perception based on ecology and proximity. EcoHealth 3 (1), 28–34.