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Environmental Sciences Division

Results of An Investigation of the Effectiveness of Using Reverse Telephone Emergency Warning Systems in the October 2007 San Diego Wildfires

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ABSTRACT

Late in October, 2007, fast-moving wildfires fueled by extreme Santa Ana winds threatened residents and their properties in San Diego County, California. The impacted area also included the City of San Diego within the County's boundaries. It turns out the San Diego firestorms would be the biggest in the County's history, surpassing the devastating 2003 firestorms in intensity, duration, and impacted populations. Both San Diego County and the City of San Diego have installed telephone reverse call-down emergency warning systems. A telephone survey of 1200 households located in areas identified by emergency officials as the evacuation zones for the 2007 was conducted in late March and early April 2008 using a random telephone dialing process to determine if people responded to the reverse 911 calls. Findings indicate that those that received a reverse emergency warning call were much more likely to evacuate than those who did not receive a call.

1. INTRODUCTION

Almost every day people evacuate from their homes, businesses or other sites, even ships, in response to actual or predicted threats or hazards. Evacuation is the primary protective action utilized in large-scale emergencies such as hurricanes, floods, tsunamis, volcanic eruptions, releases of hazardous or nuclear materials, fires, and explosions. Although often precautionary, protecting human lives by temporally relocating populations before or during times of threat remains a major emergency management strategy. One of the most formidable challenges facing emergency officials is evacuating residents for a fast-moving and largely unpredictable event such as a wildfire. How to issue effective warnings to those at risk in time for residents to take appropriate action is an on-going problem. To do so, some communities have instituted advanced communications systems that include reverse telephone call-down systems or other alerting systems to notify at-risk residents of imminent threats. This study sought to examine the effectiveness of using reverse telephone call-down systems for warning southern California residents of wildfires in the October of 2007.

Background

Late in October, 2007, fast-moving wildfires fueled by extreme Santa Ana winds threatened residents and their properties in San Diego County, California. The impacted area also included the City of San Diego within the County's boundaries. It turns out the San Diego firestorms would be the biggest in the County's history, surpassing the devastating 2003 firestorms in intensity, duration, and impacted populations. The exceptional response by San Diego County emergency officials in managing the fires - at the height of the event seven separate fires were burning simultaneously in San Diego County – has been largely credited to the lessons learned from the 2003 fires, procurement of new equipment, and on-going coordinated training and exercises. It should be noted that the City and County have separate, but coordinated emergency management and response responsibilities and have worked to obtain as much interoperable communications as possible since the 2003 wildfires.

Both San Diego County and the City of San Diego have installed telephone reverse call-down emergency warning systems. The County installed one after the 2003 Cedar fires and the City of San Diego a similar one in the summer of 2007. Both systems are sold under the "Reverse 911" trademark, although other commercial systems are also marketed. During the wildfires emergency officials decided to use the systems to initiate "be prepared to evacuate" advisories as well as issue mandatory evacuation orders to people in the affected areas. Although telephone emergency call warning systems typically rely on land-line telephones, residents who preferred cell-phones for emergency notification messages had been urged to register their cell-phone numbers with emergency call system operators. However, at the time of the firestorms only 10,000 of the 450,000 households in the City of San Diego had registered their cell-phones for emergency advisories. Recent research indicates less than ten percent of California

households have cell-only telephone systems, with the vast majority having land-lines (Blumberg, 2009).

Using the survey services provided by the Mississippi State University's Social Science Research Center, researchers from the Oak Ridge National Laboratory (ORNL) were able to obtain data about resident's behavior by using a vetted questionnaire to investigate how effectively the telephone emergency warning system operated in the fast-moving hazardous event through random telephone interviews with 1200 households in the evacuation areas. The subsequent analysis was performed on responder's answers at ORNL using the SSPS software package.

Spurred by rampart population growth in the last few decades, Californians have moved into the foothills and canyons of what is now called by researchers as the urban/wildland interface where hazardous events such as wildfires are more likely to happen. Thus many California residents are familiar with wildfires driven by the capricious Santa Ana winds blowing across the mountains from the dry, hot prairies of the central western United States. Because of the concern for wildfire destruction of homes and property, the State of California developed a comprehensive public awareness campaign to encourage property owners to protect themselves from wildfire damages based on the control of fuel sources, retrofitting of structures, and public information programs. Still, the potential for a severe wildfire hazard continues to threaten the residents of the canyons and hills that proliferate across the state. The Federal Government has been proactive in trying to reduce the potential for wildfires (US Department of Interior, 1995) albeit developing a warning strategy has not been a part of that planning. The 2007 wildfires in San Diego County (that includes the City of San Diego) were no exception to the fact that, no matter what preventable actions are taken, wildfires continue to be a menace to California residents living in harm's way.

The San Diego wildfires that we investigated for warning response started at 9:30 Pacific Standard Time on October 21, 2007, near the U.S./Mexican border. The fires, finally contained on November 9, 2007, burned a total of 368,340 acres, destroyed 1,600 structures, and resulted in 10 civilian deaths and numerous firefighter injuries.

All warnings issued by either the city or county were to evacuate or prepare to evacuate. To our knowledge no warnings to shelter-in-place were issued. The warnings were short and direct, lasting from 15 to 22 seconds. Later the County would use the same system to convey health protection messages – such as when it was safe to use the potable water system again.

The Harris Fire was the first fire to erupt (cause unknown) at 9:23 am October 21 with Santa Ana winds of 30-40 mph driving the fire westward. It resulted in thousands of advisory and mandatory evacuations throughout southern San Diego County that were issued through a variety of channels. At 10:30 am the first reverse telephone emergency calls were made to 70 residences facing an immediate threat. At 12:41 am the reverse telephone emergency call mandatory evacuation messages were issued to 700 residences in Tecate, CA, an unincorporated community bordering Mexico. At 1:38 pm the sheriff

ordered further mandatory evacuations using the telephone emergency call system to alert 322 residents of the Dulzura area.

The Witch Creek Fire ignited a few hours after the Harris Fire in Witch Creek Canyon near Santa Ysabel. With Santa Anna winds gusting over 100 mph in some areas, the fire jumped Interstate15 and continued west, causing significant damage and burning a total of 197,990 acres. It was the largest of the 2007 wildfires.

The Rice Canyon fire that started on October 22 eventually burned 9, 472 acres, resulting in a temporary closure on Interstate 15 and causing thousands of residents to evacuate in the northern part of San Diego County. That same day the Rice Canyon fire ignited, a structure fire on the La Jolla Indian reservation started the Poomacha Fire that quickly spread to Palomer Mountain where it joined the Witch Creek Fire and entered the Aqua Tibia Wilderness Area. The Poomacha Fire eventually burned 49, 410 acres and was the last fire to be contained on November 9, 2007. Other fires that needed containment included the Marine Corps Camp Pendelton Fires as well as the Coronado Hills Fire, the El Capitan Fire, and the McCoy Fire. Figure 1. depicts the general evacuation areas in the city and county as well as the boundaries of the fires.

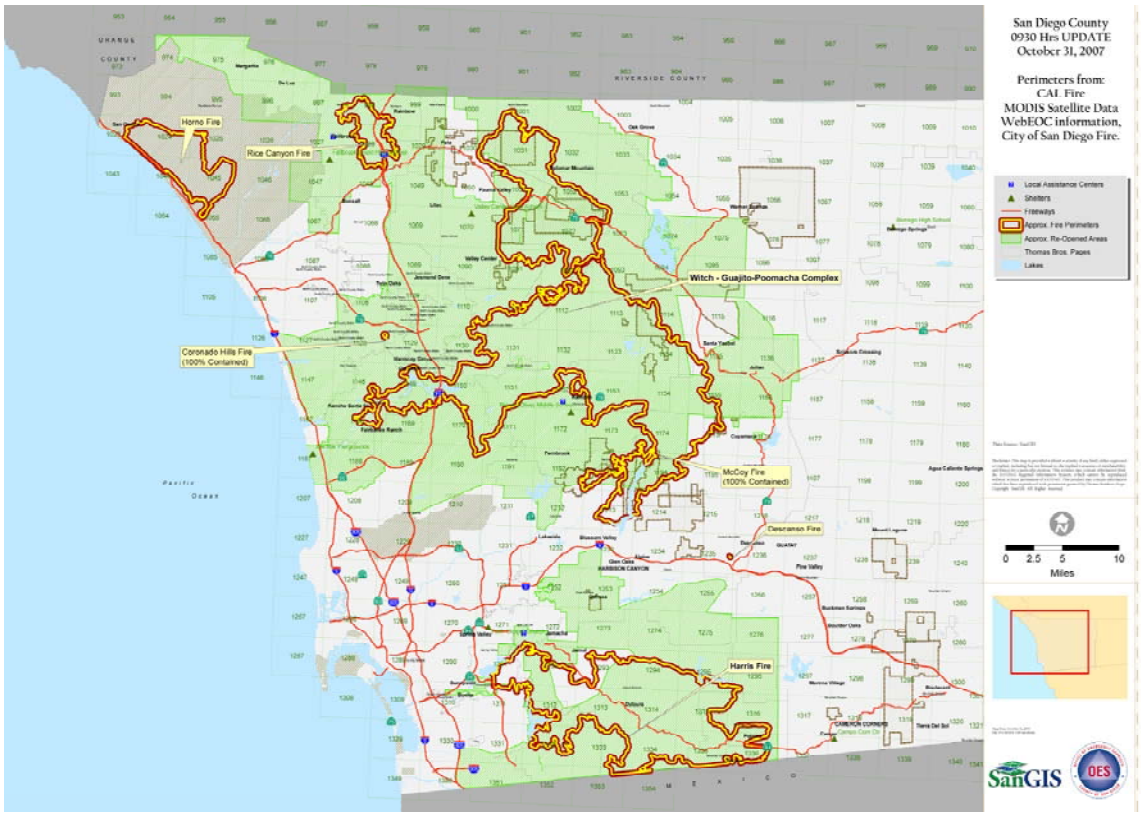

Figure 1. Geographical Areas Impacted (Source: San Diego County OES)

Appendix A lists the telephone emergency calls made to evacuate according to the fire, time of day, location targeted, and number of calls attempted. The call-down was not a saturation effort to blanket the entire area at potential risk. Instead, areas were selected because they were directly in harms way. The reverse telephone emergency call system was extensively used in the County, but was of limited use in the City of San Diego. In the county 233,590 calls were made and in the city 14,738 calls were made (San Diego County and San Diego City, 2008). Since it was estimated that over 500,000 people evacuated, many likely did so without receiving a reverse telephone emergency call.

Other estimates of the use of the reverse telephone systems vary. Seanlon (2008) reported that the city made over 100,000 evacuation calls and the county made a total of 415,000 calls, many in support of reentering evacuated areas or for public health advisories. The San Diego City Attorney's Report (Aguirre, 2007) stated that the city made limited reverse 911 calls in support of evacuation warnings.

Total projected damage costs for the 2007 San Diego County wildfires were estimated in excess of $1.5 billion. During the course of the 2007 fires, officials estimated that 515,000 county residents were in areas that received voluntary or mandatory evacuation notices. During the height of the event many schools were closed and major freeways shut down for extended periods. County residents were also urged to remain off the roads to facilitate fire-fighting efforts in gaining access to the affected areas.

Data Collection

A telephone survey of 1200 households located in areas identified by emergency officials as the evacuation zones for the 2007 wildfires (see Figure 1) was conducted in late March and early April 2008 using a random telephone dialing process. The surveys were conducted by the Survey Research Center at Mississippi State University. Table 2. summarizes the status of telephone calls made during the survey.

Table 2. Survey status of telephone interview calls.

1,210	Completed interviews
768	Respondent refused to participate
27	Incomplete interviews (respondent prematurely ended interview)
233	Household not in area affected by 2007 wildfires
4,981	Bad telephone numbers (fax machine, office telephone)
315	Communication problem (non-English speaker, health problems, deaf)
3,536	No one available (answering machine, no answer, busy signal)
1,134	Incomplete callback (callback scheduled, but quota was met before callback)
12,204	Total telephone numbers dialed

2. WARNING RESPONSE RESEARCH

Previous studies of fast-moving hazardous events have found that citizens rely on certain information sources more than others, view some as useful but dismiss others, and respond more rapidly in response to different warning mechanisms. However, analysis about the effectiveness on the use of reverse telephone calls to notify of evacuation orders has not been well documented.

The empirical study of public evacuation and response to emergency warnings has been on-going for almost 50 years (Perry and Mushkatel, 1986; 1984; Leik et al., 1981; Quarantelli, 1980; Baker, 1979; Mileti and Beck, 1975; Drabek and Stephenson, 1971; Lachman et al., 1961). These studies, when viewed collectively, have compiled an impressive record about how and why public behavior occurs in the presence of impending disaster or threat. For example, it is well documented that emergency warnings are most effective at eliciting public protective actions like evacuation when those warnings are frequently repeated (Mileti and Beck, 1975), confirmatory in character (Drabek and Stephenson, 1971), make specific recommendations and are perceived by the public as credible (Perry et al., 1981). Informal warning mechanisms (friends or relatives) are also at times very effective. In many evacuations people leave the area at risk before an official warning is announced. Evacuation behavior is also influenced by other factors such as personal or family resources, age, social relationships including social networks, level of education completed, experience with previous emergencies, social and environmental cues of immediate hazard, physical or psychological constraints to evacuating, as well as other more specific circumstances (such as time of day, weather conditions, etc.). Appendix B provides a list of those factors and how they have co-varied with decisions to evacuate.

Studies that have used surveys of random samples of people living in or near evacuation areas have been conducted for a variety of hazard events. For hurricanes these include: Elena and Kate (Baker, 1987; Nelson et al, 1988), Eloise (Windham et al., 1977, Baker, 1979), Camille (Wilkenson and Ross, 1970), David and Frederick (Leik et al., 1981), Carla (Moore et al., 1964), Floyd (Dow and Cutter, 2002; HMG, no date), Andrew (Gladwin and Peacock, 1997), Bertha and Fran (Dow and Cutter, 1998), Georges (Dash and Morrow, 2001; Howell et al., 1998), Brett (Prater et al., 2000), Bonnie (Whitehead et al., 2000) Ivan (Howell and Bonner, 2005), and Lily (Lindell et al., 2005).

Studies of flood evacuations include Denver, CO, (Drabek and Stephenson, 1971), Rapid City, SD, (Mileti and Beck, 1975), Big Thompson, CO, (Gruntfest, 1977), Sumner, Valley, Fillmore, and Snoqualmie, WA, (Perry et al., 1981), Abilene, TX, (Perry and Mushkatel, 1984), Clarksburg and Rochester, NY, (Leik et al., 1981), and Denver, CO, and Austin, TX, (Hayden et al., 2007).

Studies of evacuations due to chemical accidents include Mississauga, Ontario, Canada (Burton, 1981), Mt. Vernon, WA, and Denver, CO, (Perry and Mushkatel, 1986),

Confluence and Pittsburg, PA, (Rogers and Sorensen, 1989), Nanticote, PA, (Duclos et al., 1989) and West Helena, AR, (Vogt and Sorensen, 1999).

Other protective action studies include the Hilo, HI, tsunami (Lachman et al., 1961), the Mt. St. Helens, WA, volcanic eruption (Perry and Greene, 1983; Dillman et al., 1984), the Three Mile Island nuclear accident, PA, (Cutter and Barnes 1985; Flynn, 1979), the World Trade Center bombing, NY, in 1993 (Aguire et al., 1998), and the World Trade Center collapse, NY, in 2001 (Averill et al., 2005).

Excellent summaries of this research currently exist (Lindell and Perry, 2004, Drabek, 1986; Mileti and Sorensen, 1990, Tierney et al., 2003; National Research Council, 2006) and will not be repeated here.

Wildfire Evacuation Research

No scientific based survey has been conducted on wildfire evacuation behavior although several excellent case studies exist. Cohn et al. (2005) examined issues from both citizen and management perspectives at three Colorado wildfires – Hayman, Rodeo-Chedeski, and Buckcout/Cave Snout. Their findings are consistent with research on other evacuations. Their findings indicate:

- evacuation can be a disruptive and frustrating experience;
- this is exacerbated by poor information and communications; and
- geocoded specific area information is needed.

Taylor et al. (2007) surveyed focus groups following the Bridge Fire and Old/Grand Prix fires near San Bernadino, CA. Eight focus groups set up community organizations were conducted to discuss resident's experience in the fires. Their findings indicate:

- people sought real-time information but rarely had access to it;
- media and official information sources rarely provided the information that residents wanted; and
- people actively searched for additional information through alternative sources.

Benight et al. (2004) conducted a case study of the Hayman and Missionary Ridge, CO, wildfire evacuees using a non-random survey technique. Their findings include:

- people used a wide variety of information sources to seek information on the fires;
- males and people with long residency times in the affected areas were less likely to evacuate; and
- people wanted more, accurate, more frequent, and more detailed mapping.

All three studies add insight into our survey results.

Thus most of the social science research conducted in the US related to wildfires has focused on community level preparedness and organizational response to wildfires, individual perceptions of fire hazards and risks, household adoption of firesafe practices, and modeling the socioeconomic risks from wildfires (Daniel et al., 2007; Martin et al., 2008).

Summary of Research Findings on Risk Communication

Empirical studies and summaries have done much to further social scientific understanding of how people process and respond to risk communications in emergencies; it has also served to inform practical emergency preparedness efforts in this nation and abroad. A summary of relevant research on human response to warnings and evacuation derived from the empirical research record can be summarized as follows.

Research indicates that people's decisions to evacuate are influenced by:
• The frequency and channel of communication of the warning. The most important dimensions of the warning frequency/channel are the number of different channels people hear the warning from, hearing from personal channels, and the frequency that people hear the warning.
• The content of the warning message. The most important dimensions of content are a description of the hazard and impacts, the predicted location of impacts, what actions to take, and when to take those actions.
• Observing cues. These include social cues (i.e., seeing neighbors evacuating) and physical cues (i.e., seeing flames or a smoke cloud).
• Aspects of individual status. These include socio-economic status (i.e., income level and education completed), age, gender, and ethnicity.
• The role(s) an individual holds in society. These include having children at home, family size (i.e., larger versus smaller), extent of kin relations, being a united family at time of the event, and greater community involvement.
• Previous experience with the hazard. People are inclined to do what they did in a previous situation.
• People's belief in the warning. Belief is not determined by the credibility of the source issuing the warning but by the frequency the message is heard.
• People's knowledge about the hazard. This includes previous information and data gained in the event or by cues.
• People's perceptions of risk. This includes perception of the threat before the event and perception of risk from the specific event.
• The extent of social interactions during the event. This includes efforts to contact others about the event, being contacted by others, and being able to confirm the message as accurate and credible.

3. DESCRIPTIVE FINDINGS

Warnings

All warning mechanisms available to the city and county were utilized in the wildfire outbreaks. This included the reverse 911 telephone emergency call system, a call-in 211 communication system, police and fire personnel going door-to-door or with loudspeakers, and on-going coverage by local media outlets. One local newspaper initiated an on-going blog on their web-site that was constantly updated to inform residents of on-going closures and emergency conditions provided by fire officials. As in any disaster an informal warning system also emerged with friends, neighbors and relatives passing on warning messages.

Our research focused on when and how people received their first warning, the penetration of warnings from different sources during the event, the total number of warnings received, and the evaluation of the effectiveness of warning sources as determined by their eventual action to evacuate the area as warned.

In our sample about 63% of the households that responded to the survey received an evacuation warning while about 37% of those that responded did not. The distribution of warning times is found in Table 3. and Figure 2.

Table 3. Date of Warning Receipt during October, 2007.

Date	Frequency	Percent
Oct. 20 – Sat.	169	14.0
Oct. 21 – Sun.	192	15.9
Oct. 22 – Mon.	282	23.3
Oct. 23 – Tues.	63	5.2
Oct. 24 – Wed.	20	1.7
After October 24	45	2.9
Subtotal	761	100
Did not receive a warning	449	37.1
Total	1210	100.0

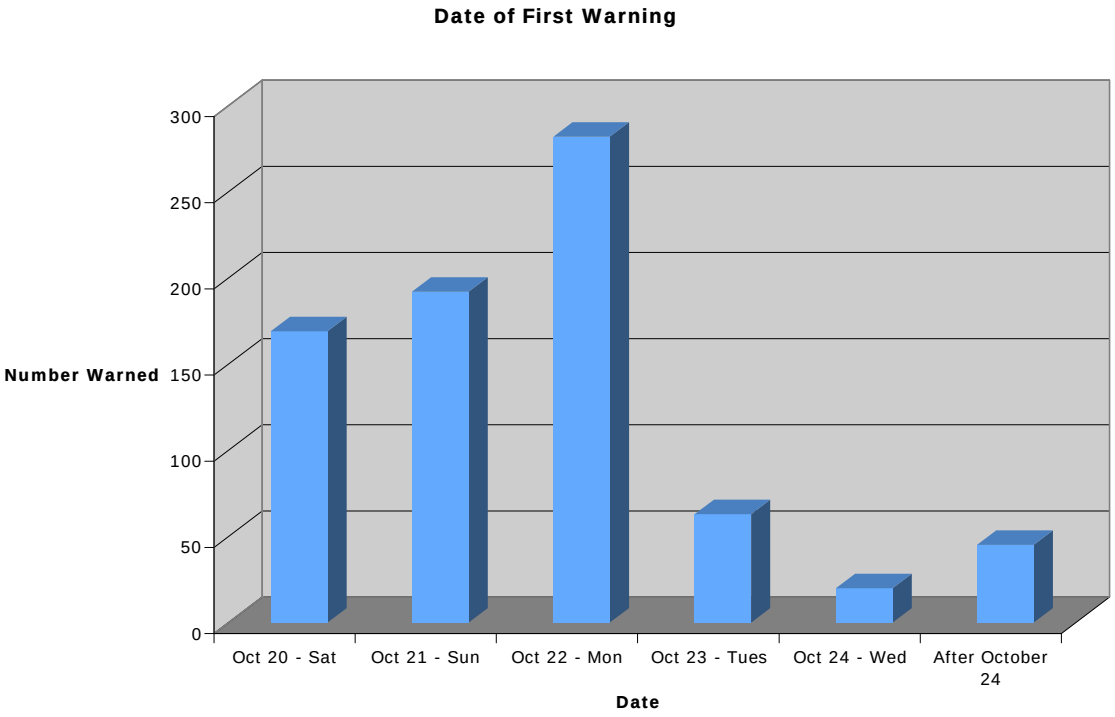

Figure 2. Date of First Warning

Over eighty percent (84.5%) of warnings were received in the first three days of the wild fires. The reverse telephone emergency calls were issued from Saturday, October 20, through Tuesday, October 23, although at a much lower volume on the 23rd. After Wednesday, October 24, few residents reported receiving a warning message. Table 4 shows how households in survey received the first warning message.

Table 4. Source of First Warning.

Source	Frequency	Percent
Reverse telephone emergency calls	510	42.1
Authority going door to door	45	3.7
Street loudspeaker	5	0.4
Tone-alert radio	4	0.3
Television	93	7.7
Radio	5	0.4
Internet	3	0.2
Telephone call	29	2.4
Face to face (informal)	46	3.8
Other	18	1.5
Subtotal	761	62.7
Did not receive a warning	452	37.3
Total	1210	100

By far the dominant initial warning came from the reverse telephone emergency call system, reaching 42.1% of the households in the survey population. The next most frequent initial warning source was television accounting for 7.7% of reported first warning sources. Informal and other official warning sources played minor roles in the initial warning receipt process. Other sources, including those from the Internet, played insignificant roles. Figure 3 shows the time of the day people received the first warning.

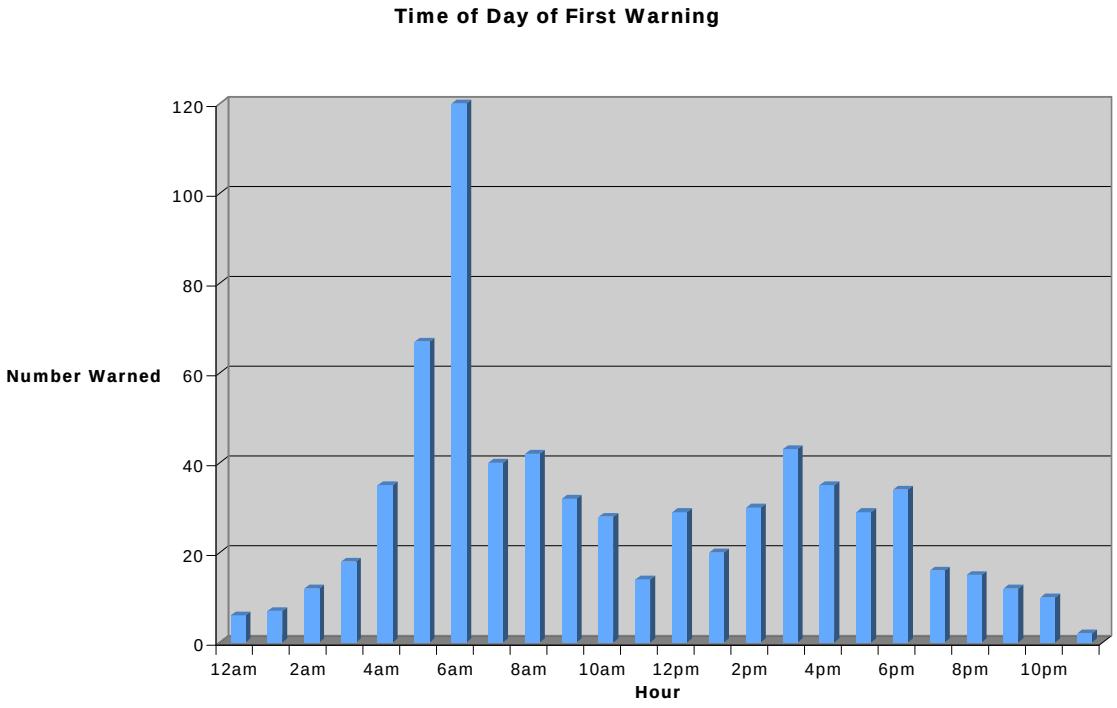

Figure 3. Time of day warning received (all days aggregated)

Most people in our sample population received warnings early in the day (from 4 to 9am) or late in the afternoon (3 to 6 pm) of October 21. Very few reported receiving a warning late at night or in the very early morning. This pattern of warning receipt is highly typical of warnings that develop over several days or longer about an on-going or changing threat.

After receiving the initial warning, households reported receiving warnings from a variety of other sources. About 6.6% received reverse telephone calls after their initial warning from another source. Television was the most frequently mentioned source (33.1%) of follow-up information. The Internet played a very minor role with only 4.9% of respondents receiving information from the web after the initial message.

Social communication among friends, family and colleagues also played a major role following the initial communication. About 45% reported contacting someone else about the evacuation warning. About one fifth (20.3%) of respondents contacted a relative about the evacuation warning, 19.3% reported contacting friends, and 29.8 % reported contacting a neighbor about the warning.

Evacuation

Evacuation occurred in selected areas throughout the officially designated evacuation zone as shown in Figure 1. Of the population sampled 59.1% evacuated, leaving 40.9% that did not. Most people evacuated over the first 4 days of the emergency. Figure 4. shows the frequency distribution of the day people departed.

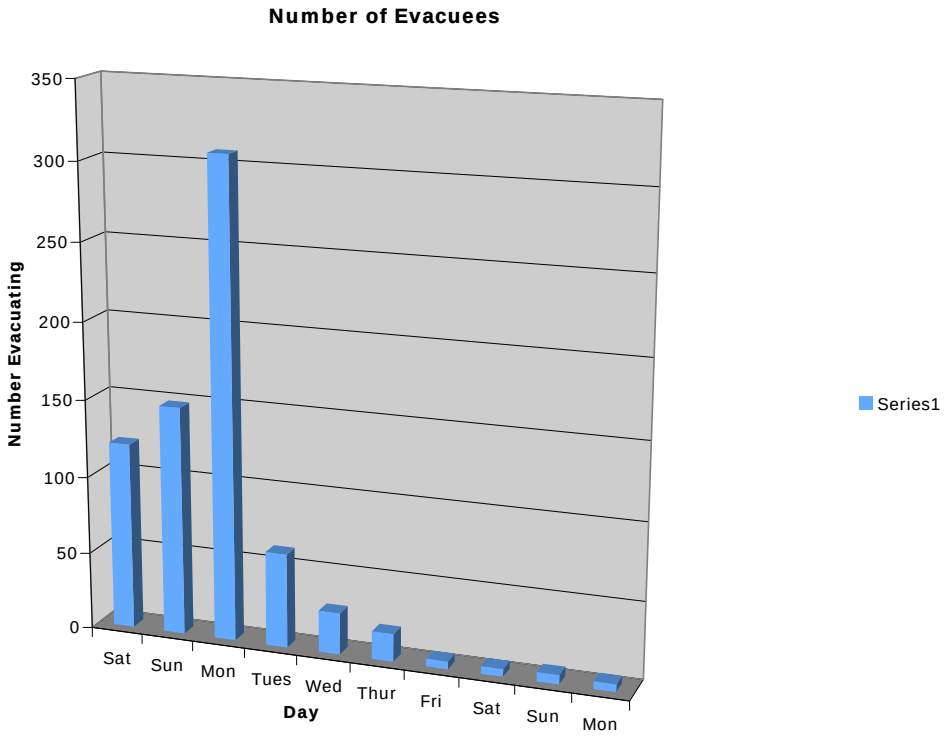

Figure 4. Day of Evacuation Correlated with Number of Evacuees.

As expected, most households evacuated on the first 3 days of the event with the largest numbers occurring on Monday, October 22 (the second day of the more severe wildfires). Table 5. presents the reasons people reported for not evacuating.

Table 5. Reported Reasons For Not Evacuating

Reason	Frequency	Percent of Sample	Percent of Non-Evacuees
Not in area told to evacuate	180	14.9	36.4
Stayed to protect property	41	3.4	8.2
Residence not threatened	274	22.6	55.4
Too expensive	5	0.4	1.0
Protect animals	18	1.5	3.6
Couldn't leave family member	8	0.7	1.6
Did not have transportation	2	0.2	0.4
Because of work	1	0.1	0.2
Other	61	0.5	12.3

Over half (55.4%) of the non-evacuees reported not feeling their property were threatened by the wildfires as the major reason for not evacuating. In addition 36.4% said they were not in an area told to evacuate. Often it is asserted that people do not evacuate to protect their property or care for animals. In this study these constraints were fairly minor reasons for not leaving. Social or economic constraints played insignificant roles in the decision to not evacuate. This may be because of the high personal incomes as reported in the Census, 2000, data.

When the wildfires broke out, most households with one or more family members were at home (96.7%). For most households (92.3%) all family members were at home before the household evacuated. Very few households needed family members to return home prior to evacuating (2.2%).

About 54% of the household had animals at home at the time of the evacuation. Table 6. shows the distribution of households with the number of animals reported at home at the time of the evacuation warnings.

Table 6. Number of Animals per Household

Number	Frequency	Percent
0	557	47.6
1	248	21.2
2	154	13.2
3	70	6.0
4	45	3.8
5	27	2.3
6	22	1.9
7 or more	27	2.3
Not/sure/refused	20	1.7
Total	1170	100

Of the households with animals that evacuated, 90.5% took their pet(s) or animal(s) with them. Less than five percent (4.2%) left them indoors while only 1.9% left them outdoors. Only 0.8% took them to an animal shelter.

As in most evacuations the majority of evacuees reported the final destination site was to a relative's or friend's residence. Some went to a hotel and motel. The other category (about 7.6 %) includes other types of destinations such as a campground or vacation home. Only 4.9% went to a public shelter. This is consistent with other research findings that indicate use of public shelters by people with higher income is usually low. Destinations of the evacuees are described in Table 7.

Table 7. Destinations of Evacuees

Destination	Frequency	Percent
Relative's home	312	43.6
Friend's home	197	27.6
Public shelter	35	4.9
Hotel or motel	79	11.0
Other	92	7.6
Total	715	100

The evacuation trip was characterized as difficult for many households. In this study 227 of the evacuating households (45.9%) reported experiencing some type of problem during the exit journey. The largest problem encountered was traffic congestion (40.6%) followed by difficulties from smoke impairment of vision (8.6%) and road closures (6.6%). Table 8. summarizes problems evacuees encounter during their egress trip.

Table 8. Problems Reported During Evacuation Trip

Problem	Frequency	Percent of evacuees
Debris on roads	16	3.2
Road closures	33	6.6
Health effects	3	0.6
Smoke interfering with vision	43	8.6
Traffic congestion	201	40.6
Vehicle problems	4	0.8
Other	10	2.0

Risk Perception

Since perceived risk of a hazard generally plays a significant role in many evacuation decisions, several dimensions of risk perceptions were measured. When asked if wildfires had ever been a problem in the respondent's immediate community, 63% of respondents indicated wildfires had been a problem, while 36% did not think they had been a problem. Respondents were also asked about the threat of wildfire in the immediate vicinity of their residence. Table 9. presents the frequency of perceived threats from wildfires among respondents.

Table 9. Perceptions of Threats from Wildfire

Threat Level	Frequency	Percent
Not a threat at all	129	10.7
A slight threat	428	35.4
A moderate threat	405	33.5
A very severe threat	228	18.9
Don't know	20	1.7
Total	1210	100

The sample was fairly evenly divided between households reporting seeing their immediate environment as at no or slight threat of wildfire versus those perceiving a moderate or severe threat of wildfires and those who perceived their immediate environment as having no threat from wildfires.

Respondents were also asked if at the time of the receipt of first evacuation warning they could see or smell any evidence of the wildfires near their residence. Of those who reported receiving a warning more than three/fourths (81.9%) indicated they had experienced visual or olfactory cues of the fires, while less than a fifth (17.7%) reportedly no evidence of a wildfire threat. This is consistent with other research findings that indicate receiving a visual, audio, or olfactory cue is often a major incentive for people to evacuate.

Demographics

Table 10. summarizes the demographics of sampled population and that of San Diego County as a whole.

Table 10. Demographic and Income Characteristics of Respondents in Sample Compared to Census 2000 Data Sources.

Item	Sampled Population	San Diego County *
White	83.6%	66.5%
Hispanic/Latino	5.6%	26.7%**
Black	1.7%	5.7%
Asian	3.8%	8.9%
American Indian	0.5%	0.9%
Pacific Islander	0.2%	0.5%
Median Income	$125,000-150,000	$47,067
Owner Occupied Housing	82.4%	55.4%
Median House Value	$700,000	$227,200
Median Age	52	33

* Source: US Census, 2000

** Can be of any race, i.e. White Hispanic (self-report)

Table 10 illustrates that the evacuation area mainly consisted of residents who were predominantly White and more affluent with higher median incomes and housing values than those of San Diego County as a whole. The sampled population also was older (median age of 52) than the county's population median age of 33. It is difficult to assess the difference between the sample and county with respect to Hispanics because of the ambiguities of self-reporting associated with defining a Hispanic heritage. From the reported ethnicity of respondents, however, it appears the sampled population likely had a much lower percentage of Hispanics than the County of San Diego as a whole.

4. EVACUATION ANALYSIS

The following variables used in our analysis of warning response correspond to the findings presented in the previous section. In this analysis the dependent variable is that coded as "Response: evacuated (yes or no)".

The independent variables include:
• Channel of communication, i.e., reported receiving warning from reverse 911 telephone calling system, from media (TV) warning, or informal warning (yes or no);
• Warning content: factor not included in analysis due to interval between warning and timing of survey;
• Observation of physical or olfactory cues, i.e., saw smoke or flames (yes or no);
• Status, i.e., income (dollars), house value (dollars), education (5 point scale);
• Role in society, i.e., age (years), rural (versus urban);
• Previous experience, i.e., had evacuated from a wildfire in the past (yes or no);
• Belief (frequency). i.e., as measured by number of warnings received from official sources (total number of warnings);
• Knowledge of preparedness actions, i.e., had prepared supply kit (yes or no), adopted mitigation measures (yes or no), believed they lived in a community where wildfires were a problem (yes or no);
• Perceptions of risk, i.e., felt residence was threatened by wildfire events (5 point scale); and,
• Social interactions, i.e., as measured by contact by friends/relatives (yes or no).

Correlation Analysis

Based on correlation analysis presented in Appendix C, the factors significantly associated with evacuation during the San Diego wildfires include the following findings. Respondents who were more likely to evacuate had:

(1) Received a warning from a reverse emergency telephone calling system. People who received an emergency telephone calling system call were more likely to evacuate than those who did not receive a call. This can be explained by two factors. First, the calls were targeted to residents in areas at high risk of imminent wildfires. Second, people are more likely to respond to personal warnings provided by the call from an official source, in this case, the county's or city's emergency services office.

(2) Received warning from media sources. People who received a warning from television media were more likely to evacuate than those who did not. People likely confirmed the initial warnings by turning to the media. When media reinforced the need to evacuate, people were more likely to comply. It is likely the media was able to show graphics and photos of the wildfires that likely enhanced the viewer's perception of threats from the wildfires.

(3) Received an informal warning. Those receiving an informal warning were more likely to evacuate than those who did not. Consistent with the research literature, informal warnings play an important role in the response process.

(4) Received a number of warnings from official sources. The more warnings people received from official sources the more likely they were to evacuate. The frequency of warnings is strongly associated with decisions to evacuate.

(5) Were contacted by someone informally. People who were contacted by friends and/or relatives were more likely to evacuate than those who were not. Informal contacts likely served to confirm the need to evacuate or made the destination site easier to choose. In this survey, 71.2% of reported evacuation destinations were to a friend's or relative's residence.

(6) Saw smoke or flames. People who reported witnessing flames or smoke in the immediate environment of their residence were more likely to evacuate than those who did not. The presence of environmental cues likely reinforced peoples perception of being in danger and that they should engage in the protective response of leaving the area.

(7) Perceived they lived in a community where wildfires were a problem. In this study respondents who perceived they lived in area where wildfires were a problem were more likely to evacuate than those who did not. This may be a function of either pre-event knowledge about wildfire hazards or pre-event perceptions that they lived in an area of potential harm.

(8) Felt threatened by wildfires in the vicinity. People who believed their residence was more threatened by wildfires were more likely to evacuate than those who believed they were not threatened. This likely resulted from information in the warnings.

(9) Lived in rural area. People who lived in a rural area were more likely to evacuate than those who lived in an urban or suburban area. This may be attributable to houses in rural areas being at greater risk from wildfires in general because of the fuel potential generally found in rural areas.

(10) Lived in lower-valued house. People living in lower-valued residences were more likely to evacuate than those who did not. One explanation was that people with less to lose were more like to evacuate. There was no correlation between housing value and the perception the respondent lived in an area at risk of wildfires.

(11) Educational level. People who were more educated were more likely to evacuate than those who had lower level of education.

Regression Analysis

In order to control for possible interaction effects not controlled for in the correlation analysis we conducted a series of regression analyses to ascertain the factors significantly

related to evacuation. Appendix D presents a summary of the results. In the first analysis we regressed all independent variables in the correlation matrix with the dependent variable of evacuation. We then eliminated all variables with a significance of greater than 0.05 ($p>0.05$) and conducted a second regression analysis with the variables where $p<0.05$. In the final analysis, 6 variables were significantly ($p<0.05$) related to evacuation behavior. These variables included:

- perception their residence was in an area threatened by wildfires,
- adoption of mitigation measures at the home,
- receipt of a reverse 911 emergency telephone system call,
- receipt of an informal warning,
- residence in a rural versus urban area, and
- seeing environmental cues (smoke or flames) of a dangerous situation.

5. REVERSE TELEPHONE CALL RECEIPT ANALYSIS

The following variables were used in the analysis of warning response in correspondence to the findings presented in the previous section.

Dependent variable used was if the respondent had received a reverse 911 telephone call, a measured by yes or no.

The independent variables included:
- channels of communication, as measured by receipt of media (TV) warning (yes or no) and/or receipt of an informal warning (yes or no);
- socioeconomic status, as measured by income (in dollar amount), house value (in dollar amount), and education level (5 point scale);
- role in society as measured in age (years), urban (versus rural) location (yes or no);
- previous experience with wildfire threat, as measured in having evacuated from a wildfire in the past (yes or no);
- knowledge of protective actions, as measured by having prepared supply kit (yes or no), adopted mitigation measures for residence or property (yes or no), and perception that wildfires were a problem in their community (yes or no); and, lastly,
- perceptions of risk from wildfires, as measured by perception that their residence was threatened by wildfire events (5 point scale).

Correlation Analysis

Based on correlation analysis (see Appendix C) the following relationships were statistically significant ($p<0.05$).

(1) Receipt of media warning. People who received a media warning were more likely to receive a reverse telephone emergency warning call. Since receiving a media warning as a first warning was very low (4%), the findings indicate that people who received a reverse telephone warning call likely turned to a media source for confirmation.

(2) Receipt of an informal warning. People who received a warning from an informal source were more likely to receive a reverse telephone emergency warning call.

(3) Owned a family supply emergency kit. People who had prepared a family emergency supply kit were more likely to receive a reverse telephone emergency warning call.

(4) Adopted mitigation measures. People who had adopted wildfire mitigation measures for their residence and/or property were more likely to receive a reverse telephone warning call.

(5) Experienced a previous evacuation. People who had prior evacuation experience with wildfires were more likely to receive a reverse telephone warning call. This may be a function of living in an area of higher threat from wildfires.

(6) Knowledge that wildfires were a problem in their community. People who perceived that wildfires were a problem in their community were more likely to have received a reverse telephone emergency warning call.

(7) Age. People who were younger were more likely to receive a reverse telephone emergency warning call. Younger people may be more likely to answer the phone or have access to telephone communications. This finding is also interesting in that current national surveys indicate that about a third of people age 18 to 24 and a fourth of people 25 to 29 live in households with only cell phones, which the reverse emergency call system was unable to contact only if the resident had self-subscribed to the service (CDC, 2009).

(8) Educational level. People who had a higher level of education were more likely to receive a reverse telephone warning call.

Regression Analysis

In order to control for possible interaction effects not controlled for in the correlation analysis we conducted a series of regression analyses to ascertain the factors significantly related to receiving a reverse emergency warning call that resulted in evacuation. Appendix D presents a summary of the results. In the first analysis we regressed all independent variables used in the analysis with the dependent variable of receiving a reverse telephone warning call. We then eliminated all variables with a significance of greater than 0.05 ($p>0.05$) and conducted a second regression analysis with the variables where ($p<0.05$). In the final analysis, 7 variables were significantly ($p<0.05$) related to receipt of a reverse telephone warning call. These variables included:

- knowledge that wildfires were a problem in their community,
- prior adoption of wildfire mitigation measures,
- experience with previous wildfires,
- receipt of a warning from media,
- receipt of a warning from an informal source,
- educational level, and
- age.

6. CONCLUSIONS

The major finding from this research concerns the effectiveness of the emergency reverse telephone notification system in prompting residents to take the protective action of evacuating. While we cannot estimate the portion of the people targeted with calls that actually received a warning message, we can say that from the population sampled in this study that the reverse telephone warning system was the dominant form of first warning among our respondents. Furthermore, those that received a reverse emergency warning call were much more likely to evacuate than those who did not receive a call. The emergency telephone notification system was one of two significant warning mechanisms identified in the study, with the other being the informal notification process. We know from previous studies that informal notifications play a significant role in the warning process. This is the first investigation of this emerging warning technology and the findings should be encouraging to communities who have adopted or are considering adopting the reverse telephone warning technology. As with any warning technology, good planning, public education and outreach programs, and community exercises and testing procedures are critical to the effectiveness of any warning system, especially if more cell phone users are to be reached using the reverse telephone warning systems. The downside is that cell phones are being used by the very young, some of elementary school age, who are incapable physically or mentally of instituting protective actions as recommended by authorities. This lends another layer of complexity in determining who the reverse telephone technology should reach in times of emergencies when quick response may be vital to saving lives.

Several findings reinforce previous warning response studies. Three variables - perception of threat, living in higher risk areas, and seeing environmental cues - were significantly related to the decision to evacuate from the wildfire.

The final significant relationship between mitigation adoption and evacuation is also important. Households who had adopted one or more wildfire mitigation measures - such as brush (fuel) clearing, installing roof sprinklers, modifying a structure to be fire resistant such as replacing roofs with fire-resistant tiles, or modifying residential landscaping - were more likely to evacuate. This suggests that taking protective actions to protect assets may help to facilitate evacuation of people and animals and overcome residents' resistance to evacuating in order to remain and protect property. It also indicates monetary resources (higher income) to implement mitigation measures.

The analysis of the receipt of reverse telephone emergency warning calls indicate three trends. First, people who received reverse telephone warning calls also received warnings from media and informal sources. Second, people receiving the reverse telephone calls likely resided in areas at higher risk of wildfires and had adopted mitigation measures, perceived their community had a problem with wildfires, and had experienced previous wildfires. Finally, two demographic variables were significant - people with higher educational levels as well as younger people were more likely to receive the reverse telephone emergency warning calls.

Overall the results of the study are encouraging from both a managerial and response perspective. The targeting of high risk areas with the reverse emergency warning calls was apparently effective in reaching the people who needed to evacuate. Second, people receiving the calls were much more likely to evacuate than those who did not. This is the first systematic study of a new warning technology deployed in recent years. Although telephone databases from system vendors can indicate how many calls were made and answered, that data does not show how effective the warnings were in promoting protective actions, especially in areas subject to risk of wildfires. In this case, the receipt of targeted information from an official source using a reverse telephone warning technology proved to be extremely effective in protecting human life by getting residents to evacuate from wildfire hazards.

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Appendix A: Emergency Telephone Evacuation Calls Made During the 2007 Wildfires

Telephone Evacuation Calls In San Diego County

Date	Fire	Time	Location	Number
10/21	Harris	10:30	unnown	70
“	Harris	12:41	Tecate	700
“	Harris	13:38	Dulzura	322
“	Witch	14:22	Ramona	8900
“	Harris	16:10	Otay Lake/Barrett Junction	700
“	Witch Creek	16:40	Witch Creek	300
“	Witch Creek	22:10	Ramona	10000
10/22	Witch Creek	01:36	Escondido	2000
“	Witch Creek	02:56	San Marcos	4300
“	Harris	03:32	Coyote Holler	970
“	Witch Creek	04:22	Poway	1900
“	Coranado Hills	05:24	Carlsbad	22770
“	Witch Creek	06:00	Del Dios	43240
“	Rice Canyon	06:14	Rainbow	36
“	NA*	06:35	Valley Center	2300
“	Witch Creek	07:36	Poway	4000
“	NA*	10:08	Rancho Santa Fe/Leucadia	17600
“	Witch Creek	10:55	Poway	8700
“	Witch Creek/Rice Canyon	12:24	Poway +	19000
“	Witch Creek	18:25	Del Mar Solano Beach, Rancho Santa Fe	34700
“	Witch Creek	20:09	Olivenhein	1640
10/23	Harris	02:43	Wildcat Canyon/Muth Valley	3800
“	NA*	03:09	North Jamul/Indian Springs	1550
“	Poomacha	04:45	La Jolla Indian Reservation/Pauma Valley	4100
“	Poomacha	06:30	Palomar Mountain	8000
“	Witch Creek	06:45	Hidden Meadows	2900
“	Rice Canyon	10:18	De Luz	1000

“	Harris	12:38	Ramona/Lakeside	1800
“	NA*	13:37	Julian	2400
“	Rice Canyon	14:33	De Luz	4000
“	Harris	14:45	Jamul	800
“	NA*	16:33	Julian	3100
“	Poomacha	17:30	Eagle Peak/ Cuyumaca	142
“	Rice Canyon	20:15	Fallbrook	14000
10/24	Rice Canyon	02:10	De Luz	900
10/25	Harris	13:54	Lawson Valley/Carveacres	950
Total				233,590

Source: Compiled from *2007 San Diego County Firestorms After Action Report*. San Diego County Office of Emergency Services.
*NA – Not Available

Telephone Evacuation Calls In San Diego City

Date	Fire	Time	Location	Number
10/22	Witch Creek	04:00	San Pasqual Valley	14738

Source: *After Action Report – October 2007 Wildfires: City of San Diego Response*. City of San Diego.

Appendix B: Factors Associated with Evacuation Behavior

Characteristics of the Warning

As Factor Increase,	Response:	Level of Support:
Channel: Electronic	Is Mixed	Low
Channel: Media	Is Mixed	Low
Channel: Siren	Decreases	Low
Personal warning vs. impersonal	Increases	High
Proximity to threat	Increases	Low
Message specificity	Increases	High
Number of channels	Increases	Low
Frequency	Increases	High
Message consistency	Increases	High
Message certainty	Increases	High
Source credibility	Increases	High
Fear of looting	Decreases	Moderate
Time to impact	Decreases	Moderate
Source familiarity	Increases	High

Characteristics of People

As Factor Increase,	Response:	Level of Support:
Physical cues	Increases	High
Social cues	Increases	High
Perceived risk	Increases	Moderate
Knowledge of hazard	Increases	High
Experience with hazard	Is Mixed	High
Education	Increases	High
Family planning	Increases	Low
Fatalistic beliefs	Decreases	Low
Resource level	Increases	Moderate
Family united	Increases	High
Family size	Increases	Moderate
Kin relations (number)	Increases	High
Community involvement	Increases	High
Ethnic group member	Decreases	Moderate
Age	Is Mixed	High
Socioeconomic status	Increases	High
Being female vs. male	Increases	Moderate
Having children	Increases	Moderate
Pet ownership	Decreases	Low

Appendix C: Correlation Matrix

	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 evac	1.41	1.00	1.000																
2 tele	1.51	.500	.307**	1.000															
3 med	1.71	.501	.146**	.456**	1.000														
4 num	1.86	1.074	-.308**	-.793**	-.322**	1.000													
5 inf	1.85	.335	.176**	.073*	.001	-.507**	1.000												
6 cont	1.45	.502	.286**	.554**	.427**	-.507	.213**	1.000											
7 sup	1.46	.503	.013	.078**	.142**	-.049	.006	.132**	1.000										
8 mit	1.56	.515	-.055	-.114**	-.077**	.105**	.017	-.071*	-.149**	1.000									
9 exp	1.77	.422	.111	.143**	.166**	-.118**	-.016	.201**	.216**	-0.165**	1.000								
10 cues	1.19	.339	.089*	.026	.055	-.014	-.047	.057	.030	-.042	-.006	1.000							
11 prob	2.65	.957	.091**	.093**	.013	-.117**	.018	.069*	.045	-.094**	.087**	.012	1.000						
12 threat	1.52	.500	-.169**	-.053	-.009	.090**	-.048	-.062*	-.057*	.126**	-.093**	-.045	-.347**	1.000					
13 loc	1.78	.412	.180**	.025	.044	-.075**	.001	.009	.055	-.211**	.096**	.015	.205**	-.225**	1.000				
14 age	53.13	15.654	-.011	.071*	.000	-.051	-.048	.079**	.006	.064*	-0.031	.113**	-.012	.042	-.072*	1.000			
15 inc	6.67	3.53	-.018	-.044	-.002	.051	.002	.002	.023	.011	.044	.024	.028	-.025	.093**	-.071*	1.000		
16 house	692.65	288.16	-.065*	-.025	.069*	.049	.001	.021	.095**	-.027	-.117**	-.001	-.016	.013	.042	-.021	.249**	1.000	
17 edu			-.083**	-140**	-.078**	.086**	.043	-.137**	.030	-.006	.030	.030	.008	-.006	.109**	-.087	.196**	.060*	1.000

* = p<.05 and **p<.01

1. evac: evacuated or did not evacuate
2. tele: reported receiving emergency telephone warning to evacuate
3. med: reported receiving a warning by TV to evacuate
4. num: number of official warnings received
5. inf: reported receiving a warning from informal source
6. cont: contacted peers about the warning
7. sup: had prepared an emergency supply kit
8. mit: had taken one or more measures to protect home from wild fires
9. exp: have evacuated in the past
10. cues: saw smoke or flames from fires
11. prob: perceived wildfires to be a problem in area
12. threat: perceived threat to residence from wildfires
13. loc: located in urban or rural area
14. age: age in years of respondent
15. inc: household income
16. house: value of residence
17. edu; level of education

Appendix D: Regression Results

Evacuation

1. Regression with all independent variables included

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.683	.245		2.791	.005
	prob	-.015	.035	-.017	-.426	.671
	threat	-.041	.019	-.086	-2.175	.030
	mit	.081	.034	.094	2.411	.016
	sup	-.010	.035	-.012	-.300	.765
	exp	.061	.040	.061	1.525	.128
	cues	.115	.041	.104	2.791	.005
	med	-.032	.034	-.037	-.934	.351
	inc	.000	.005	-.007	-.179	.858
	edu	-.028	.022	-.049	-1.274	.203
	house	-6.433E-5	.000	-.041	-1.069	.285
	num	-.035	.035	-.045	-1.003	.316
	cont	.049	.039	.049	1.265	.206
	age	-.002	.001	-.057	-1.497	.135
	loc	.174	.041	.169	4.296	.000
	tele	.117	.050	.108	2.355	.019
	inf	.131	.041	.126	3.221	.001

a. Dependent Variable: evacuated (yes or no)

2. Regression with reduced variables

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.469	.155		3.016	.003
	threat	-.051	.017	-.107	-2.972	.003
	mit	.073	.031	.084	2.315	.021
	cues	.099	.039	.088	2.509	.012
	loc	.162	.038	.153	4.203	.000
	tele	.148	.039	.138	3.771	.000
	inf	.140	.038	.133	3.653	.000

a. Dependent Variable: evacuated (yes or no)

1. evac: evacuated or did not evacuate
2. tele: reported receiving emergency telephone warning to evacuate
3. med: reported receiving a warning by TV to evacuate
4. num: number of official warnings received
5. inf: reported receiving a warning from informal source
6. cont: contacted peers about the warning
7. sup: had prepared an emergency supply kit
8. mit: had taken one or more measures to protect home from wild fires
9. exp: have evacuated in the past
10. cues: saw smoke or flames from fires
11. prob: perceived wildfires to be a problem in area
12. threat: perceived threat to residence from wildfires
13. loc: located in urban or rural area
14. age: age in years of respondent
15. inc: household income
16. house: value of residence
17. edu: level of education

Reverse 911 call

a. Regression with all independent variables included

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.597	.172		3.458	.001
	prob	.088	.027	.091	3.292	.001
	threat	-.003	.015	-.005	-.193	.847
	mit	-.063	.026	-.065	-2.406	.016
	sup	-.015	.027	-.015	-.574	.566
	exp	.097	.032	.082	3.020	.003
	media	.477	.028	.455	17.257	.000
	income	-.003	.004	-.021	-.784	.433
	edu	-.059	.016	-.098	-3.721	.000
	house	-7.865E-5	.000	-.045	-1.701	.089
	loc	-.002	.033	-.002	-.065	.948
	inf	.118	.036	.084	3.257	.001
	Age	.002	.001	.076	2.934	.003

a. Dependent Variable: Received 911 Call (yes or no)

2. Regression with reduced variables

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.531	.152		3.491	.001
	prob	.091	.025	.094	3.640	.000
	mit	-.062	.026	-.064	-2.425	.015
	exp	.087	.031	.073	2.759	.006
	media	.472	.027	.451	17.224	.000
	edu	-.064	.016	-.106	-4.079	.000
	inf	.118	.036	.084	3.255	.001
	age	.002	.001	.078	3.009	.003

a. Dependent Variable: Received 911 Call (yes or no)