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Flash Flood Awareness in Southwest Virginia

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Flash floods are one of the most dangerous weather-related natural disasters in the world. These events develop less than six hours after a rainfall event and create hazardous situations for people and extensive damage to property. It is critical for flash flood conditions to be warned of in a timely manner to minimize impacts. There is currently a knowledge gap between flood experts and the general public about the level of perceived risk that the latter has toward the powerful flood waters and how events should be warned of, which affects the communication capabilities and efficiency of the warning process. Prior research has addressed risk perception of natural disasters, but there is little emphasis on flash floods within flood-prone regions of the United States. This research utilizes an online survey of 300 respondents to determine the current state of flash flood awareness and preparation in southwest Virginia. Analysis of trends involved the use of chi-squared tests (χ^2) and simple frequency and percentage calculations. Results reveal that a knowledge base of flash floods does exist, but is not advanced enough for proper awareness. Young adults have a lower understanding and are not as concerned about flood impacts. Increased exposure and perceived risk play a key role in shaping the way a person approaches flash floods. People do monitor flood events, but they are unaware of essential guidance and communication mechanisms. Finally, results suggest that the current method of warning about flash floods is not provided at an appropriate level of detail for effective communication.

KEY WORDS: Flash flood; natural disaster; risk perception; survey analysis; Virginia

1. INTRODUCTION

1.1. Problem Statement

Droughts, wildfires, winter storms, hurricanes, tornadoes, and floods are all weather-related natural disasters that affect the world year round. Ranking second only behind wildfires in frequency,[1] flooding is the costliest and deadliest weather-related natural disaster in the United States with nearly 9,000 confirmed deaths in the 20th century[2] and more than $2 billion in annual property damage.[3] In fact nearly 90% of all natural disasters in the United States involve flooding.[1] These statistics can certainly be supported by the aftermath that the Gulf Coast experienced from Hurricane Katrina.

Flash floods can develop at a very rapid rate with little or no warning, as these events are defined to be a flood that occurs within six hours of a rainfall event.[4] When flash flood conditions become likely or imminent, the public needs to be warned in an informative and timely manner to minimize impacts. This process includes the recognition of precipitation onset, the collection and evaluation of data by human analysts or automated systems, threat recognition, notification, decision generation, response activation, and public action and mitigation strategies.[5] The short timeframe associated with these events does not leave

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any margin for error within the entire warning process.

In order for this process to evolve in an effective manner, before a flood commences, there needs to be a seamless connection between hazard experts and the general public. There is currently a knowledge gap between these two groups that can complicate the communication of dangerous events.[6–8] Experts underestimate the level of risk that the public perceives in hazardous events, while the public overestimates the level of risk experts perceive.[6] This mutual misunderstanding of beliefs and values has been illuminated as a source of the hazard communication breakdown and also has led to suspicion about a lack of honesty between the two sides. Hazard notification processes and mitigation strategies developed by experts typically focus on the physical attributes that describe the science, magnitude, and frequency of an event, but rarely consider the meaning these physical characteristics have for people or their relationship to risk reduction behavior.[7] Conversely, people confronted with complex issues and warnings concerning events that they are unfamiliar with may transfer all responsibilities for their preparation and protection to the experts.

Thus, it is important for experts to develop risk communication strategies for public use that build on common knowledge, beliefs, needs, and expectations rather than simply providing information that reflects the level of intelligence and expectations of the scientific community. In order for experts to obtain a better means of warning the public, it is essential for them to have a clear understanding of the public's perception of the hazardous event that they are forecasting. Perceived risk has been linked to issues such as proximity to the hazard source, likelihood of future disasters, the perceived extent of impacts, and past experience in disasters.[7] In terms of flash floods this would include understanding of flood-related risks, previous interaction with flash floods, reaction and response in flood conditions, awareness of available warning methods, and a preferred warning process. In light of recent disasters along the Gulf Coast of the United States and the role that public perception and knowledge played in evacuation, the importance of effective risk communication cannot be overemphasized.

1.2. Related Literature

The theoretical basis for this research is found within the natural hazards literature and is also informed by work in water resources research that deals with vulnerability to flooding. More specifically, this study is situated within risk analysis, considered a subfield of hazards research.[9] While an exhaustive review of the literature in risk and vulnerability analysis, particularly as it pertains to floods, is constrained by space, significant early and more recent studies that contribute conceptually to the research presented in this article are reviewed.

Over the past 50 years, Gilbert White's influential studies have contributed greatly to research on flood exposure, response, and risk perception. His work has examined a broad spectrum of social factors related to flash floods, and he has observed a number of significant findings. In a study of the perception of flood hazards and adjustments made by floodplain managers in six communities in the United States, a strong association was found between the adoption of emergency measures and the recent occurrence of a major flood.[10] Another study of flood impacts was part of a larger examination of natural hazards in the United States where interactions between social and natural systems were studied along with the potential adjustments to minimize loss of life and property.[11] Scale is an important concept within studies of hazards, and in this vein, White edited a volume on hazards and the human response at different scales.[12] Within that volume, Beyer examined the range of potential adjustments that can be made to floods and summarizes the results of hazard perception studies; generally, knowledge and understanding about floods does not guarantee that the public will make decisions to protect themselves.[13] More recently, White has offered seven observations from research examining hazards, some of which are relevant to the research presented here: the consequences of natural events are the result of interactions between human and physical systems, the perception of those affected by an event needs to be considered in any risk analysis, and hazards studies should include an examination of the characteristics of those affected, including "age, gender, income, education," and past flood experience (Reference 14, p. 173).

In addition to White's contributions to the examination of flood risk perception, there is an abundant body of research within this area, and several studies or literature reviews pertinent to the study presented here will be briefly discussed. Montz *et al*. state that vulnerability studies dominate much of the work conducted in hazards research, and point out that while our understanding of physical processes within the environment has increased, our vulnerability to natural hazards has also increased in many locations.[15] In

addition, Cutter reports that while the methods used to examine vulnerability are diverse, most studies of hazard vulnerability incorporate aspects of the political and economic structures within a place to more fully understand the public's ability to cope with a certain hazard.[16] Building on studies of risk perception, Kasperson *et al*. examine the ways in which risk can be amplified, even for relatively minor risk events, and report that perceptions of hazards by the public can either be calmed or increased based on the social, cultural, and psychological background of the individual or the public at large.[17] Also, the experience that one has had with the hazard provides feedback for an appropriate response, and if direct experience is absent then perception is developed based on information from others or from the media.[17]

Natural disaster risk perception and awareness surveys have been performed for various hazards in a variety of locations. Research on risk perception and preparedness of volcanic hazards in New Zealand found that anticipation of the likelihood of an eruption is closely related to the corresponding level of preparation, and that the public frequently has a low personal interest in risk but a high expectation of government responsibility.[18] Another study of the perception of volcanic risk performed in Hawaii found that awareness of volcanism in the study community is extremely high, but this attribute does not translate into knowledge of future threats and proper preparations.[7] A review of related literature by Gruntfest *et al*. included surveys of hurricane awareness that found that the public considers many sources and factors before making evacuation decisions, emergency management plays a major role in evacuation information, and repeat evacuations do not negatively affect the public's view of emergency management practices.[19]

1.3. Objectives

There have been a few survey studies directly related to floods as well. A survey of risks associated with damage after a major flood event in Japan in 2000 found that major property risk factors included household characteristics such as the type of dwelling, ownership, and inundation extents.[20] A second study of this flood found that previous experience with flooding does not necessarily bolster awareness and preparedness for future floods, homeowners and renters prepare for floods differently, and preparedness for floods is determined by perceived fear of floods and damage exposure.[21] An extensive evaluation of flood warning systems and awareness in Colorado concluded that there is a low level of public knowledge of basic flash flood information that varies by demographic group, awareness of flood risk to property is greater than risk to life, and respondents would rather be overwarned than underwarned.[19]

These studies have addressed risk perception for flash floods utilizing surveys, but they did not consider flood concerns within flood-prone regions of the southeastern United States. The research presented here contributes to this body of natural disaster perception literature by introducing new flood awareness characteristics and trends within a flood-prone region that has not been addressed before. This study utilizes a survey to assess flash flood awareness levels within the New River and Roanoke Valleys of southwestern Virginia. The aim of this research is to determine the current state of flash-flood-related knowledge and awareness for the general public in this region. This includes the public's perception of flash floods, their experience with flash floods, how they track the weather and flash floods, their reaction to flash flood events, and their response during flash flood conditions. Obtaining a better knowledge of the general public's understanding of flash-flood-related issues will help flood experts generate the best possible method of predicting and warning of these events. Insight into the public's perception of flash floods will also help to bridge the knowledge gap between experts and the general public. The results of this research can answer some of the essential questions in regard to effective communication of hazardous events.

2. BACKGROUND

2.1. Study Area

Nestled within the Appalachian and Blue Ridge Mountains, southwest Virginia is a rural region dotted with small towns and cities and straddled by two metropolitan cities, Roanoke to the east and Bristol to the west. Flash floods can develop from intense rainfall associated with precipitation events, severe thunderstorms, hurricanes, or after rapid snowmelt from winter weather events, and all have the potential to create flooding in this study area (Fig.1).

The Gulf of Mexico and Atlantic Ocean moisture, prevailing weather patterns, and complex topography of this region combine together to create a variety of precipitation sources throughout the year. Spring is characterized by occasional winter weather

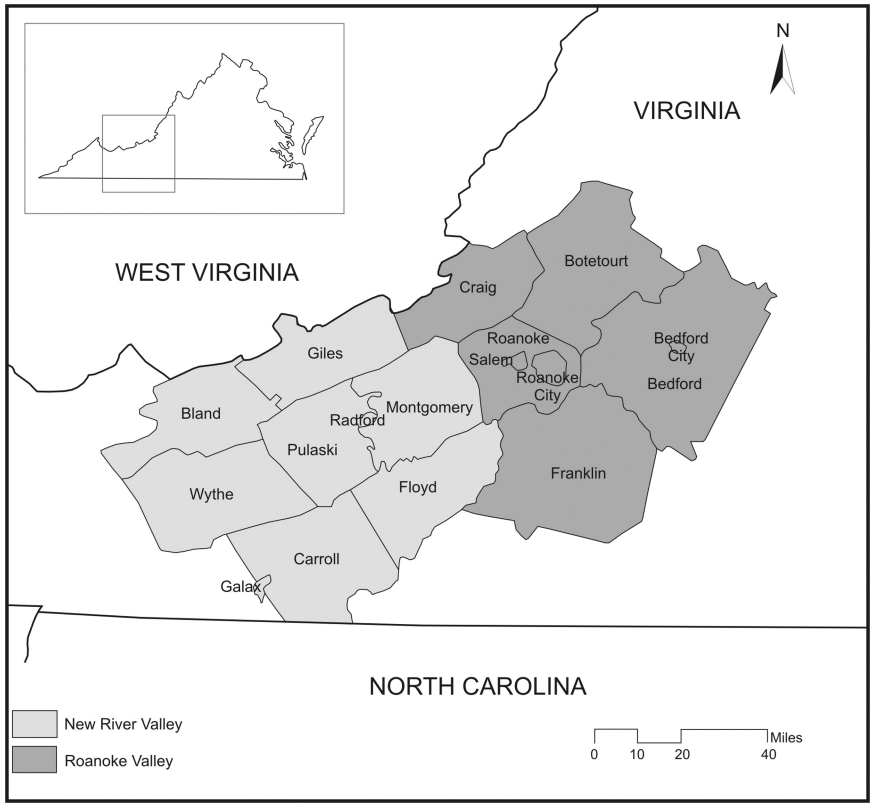

Fig. 1. Map of southwest Virginia, including the New River and Roanoke Valleys.[24]

events and rainfall from frontal systems. Summer precipitation is received from frontal systems, convective storms, orographically induced rainfall along ridgelines, and tropical systems. Fall shifts back into a predominantly frontal pattern, with lingering tropical systems and a gradual transition back into frozen precipitation. Finally, winter comes with a dose of liquid and frozen precipitation from frontal systems, Nor'easters, and occasional lake effect events off of the Great Lakes. Annual precipitation in southwest Virginia is typically 35–45 inches,[22] with the majority of this moisture flowing into the New River and Roanoke River Basins. The New River watershed is approximately 3,068 mi^2 while the Roanoke River watershed is approximately 6,274 mi^2.[23] Both watersheds experience seasonal flow regimes with a peak discharge in the late winter/early spring and a minimum in late summer/early fall; average annual discharge in the New River (measured at Radford, VA) is 3,867.5 $feet^3$/second while average annual discharge in the Roanoke River (measured at Roanoke, VA) is 374.4 $feet^3$/second.[25]

Flooding has ravaged this region multiple times in the past two years alone, which is the main impetus for improving public awareness. Table I lists selected major historical flood events in the New River and Roanoke Valleys. The wide variety of dates within this table shows that flash floods are a year-round event that can pose a risk to people and property at any time.

2.2. Flood Risk

Risk can be broken down into many categories; ranging from how individuals receive and process risk information and their role in risk attenuation[29] to issues of the magnitude of the event, socioeconomic scale and vulnerability, and risk perception[21] to addressing the potential for catastrophic results and the element of uncontrollability[8] to the basic probability that an event might occur.[30] The two types of risks that individuals routinely face are voluntary risks and involuntary risks. Voluntary risk involves an event where the individual is aware of the event's

Table I. Selected Major Historical Floods in Southwest Virginia[26–28]

Date	Event	Peak Height Above Flood Stage (feet)	
		New River – Radford[1]	Roanoke River – Roanoke[2]
June 21–24, 1972	Hurricane Agnes	6.2	9.6
November 4–7, 1985	"Election Day Flood"		13.4
January 19–22, 1996	"The Great Melt Down"	5.8	2.5
September 6–8, 1996	Hurricane Fran		3.9
February 21–22, 2003		1.1	5.5
November 18–20, 2003		5.5	
September 8–9, 2004	Hurricane Frances		2.7
September 28–30, 2004	Hurricane Jeanne	0.95	7.8

[1]Flood stage for the New River in Radford is 14 feet.
[2]Flood stage for the Roanoke River in Roanoke is 10 feet.

occurrence, is willing to participate in the event, and accepts the consequences that may develop. On the other hand, involuntary risk is associated with events where individuals are unaware of the onset of the event, they did not choose to associate with the event, and they have no control over how the event will affect them.

Flash floods fall under the category of an involuntary hazard because they are uncontrollable disasters that can rapidly develop without warning. For these involuntary events, greater concern has been connected with a higher frequency of past experience with flood events, greater impacts associated with previous experiences, and the level of exposure to negative outcomes.[29] These issues of risk, frequency, experience, impacts, concern, and knowledge are difficult to sense in terms of an overall public view and are sometimes even overlooked by flash flood experts.

2.3. Survey Analysis

An effective way to assess the problems addressed above is to survey the general public about flash flood awareness. There are three basic reasons for utilizing a survey: to influence or persuade some audience, to create or modify a product or service, and to understand or predict human behavior or conditions.[31] Three classes of data exist within survey questions: data that categorize and describe people, data that characterize behavior of people, and data that reveal attitudes, opinions, and beliefs.[32] Typical topics used to address these data attributes include: knowledge, experience, attitudes, images, decisions, needs, behavior, lifestyles, affiliations, and demographics.[31]

3. METHODS

3.1. Survey

A survey of flash flood awareness within southwest Virginia was deemed to be the most appropriate method for meeting the aims of this study. The survey focuses on topics related to prediction and notification, public perception and preparation, and reaction before and during the event because these are the times when vulnerability is highest within flash flood events. The survey audience was the general adult public, so the only requirements of participants were: residence in the study region (New River or Roanoke Valley, Fig. 1) and an age over 18 years. Demographic attributes monitored within the survey included: gender, age, educational status, zip code, length of residency in the region, housing status, and whether the individual lived in a floodplain and/or had flood insurance. Age groups are similar to census categories but were broken down based on lifestyles (students and young adults, early career, near retirement, retired, and elderly) to determine any significance. Perceptive questions that were addressed included the ability to define a flash flood and understand flash flood statistics, risk perception, life and property issues, and past flash flood frequency and experience. Reaction and preparation attributes within the survey included weather monitoring characteristics, information sources, reaction to weather watches and warnings, relative fear of weather-related natural disasters, preferred method of warning (scale and timing), and knowledge of current warning systems.

3.2. Sample

In order to attain accurate and meaningful results for a survey of the general public, it is important to

Table II. Demographic Comparison Between Sample and Total Populations[34]

2000 Census		Survey		2000 Census		Survey	
Gender (18+)		Gender (18+)		Housing		Housing	
Male	48%	Male	52%	Owner-occupied units	71%	Owner	72%
Female	52%	Female	48%	Rent-occupied units	29%	Rent	22%
						Nonpaying resident	6%
Age		Age		Education (25+)		Education (18+)	
15–19	9%	18–25	17%	9th–12th, no diploma	15%	Some high school	2%
20–24	10%	26–40	33%	High school graduate	34%	High school diploma	11%
25–34	16%	41–55	36%	Some college, no degree	22%	Some college	31%
35–44	18%	56–70	12%	Associate degree	7%	Bachelor's degree	34%
45–54	18%	71+	2%	Bachelor's degree	14%	Graduate degree	22%
55–59	7%			Graduate/professional degree	9%		
60–64	5%						
65–74	9%						
75–84	6%						
85+	2%						

have a sample size that is large enough to produce significant results and also be representative of the total population. The correct sample size hinges on the desired confidence level, the degree of reliability, and the degree of validity. The majority of available statistical tests based on a normal distribution that can be performed on quantitative survey results require a minimum of 30 respondents. As sample size increases, confidence limits initially decrease quite rapidly and then gradually decline between 250 and 300 respondents at an error range of 10% around the sample mean.[31] It may be thought that increasing the sample size to levels above a few hundred will continue to reduce the sampling error, but beyond a certain point a large increase in sample size does not translate into significant error reductions.[33] For this flash flood awareness survey, a sample size of 300 was chosen because it is at the upper end of the sample range where confidence levels even out at 10% and begin their gradual decline as described above.

3.3. Implementation

A draft survey was compiled from the set of aforementioned question themes and then tested in a pilot setting by a variety of individuals (experts, knowledgeable respondents, the general public, college students, etc). Adjustments to the wording and flow of questions were made based on feedback from the pilot survey to devise the final survey. The method of distribution for this survey was selected to be online because this was the most effective and efficient means of reaching the general public within the geographical boundaries of the study area. This approach did introduce some bias in results since members of the general public without access to the Internet were likely excluded. The survey was developed and distributed using the web hosting service called "survey.vt.edu" available through Virginia Tech. Media outlets used to inform the public about the survey included local television stations, newspapers, websites, list-serves, e-mail, and manual collection at a local bowling alley. The data collection period was six weeks, from March 12, 2005 to April 25, 2005.

When data collection ended, there were a total of 329 respondents that had accessed the survey and submitted results. Of this total, 29 of the responses had to be removed either because the respondent did not reside within the boundaries of this study area, the respondent did not provide a zip code location, or the respondent submitted a blank survey. A small portion of the remaining 300 respondents did not answer every question, so some questions had slightly fewer than 300 responses. Table II provides a demographic comparison between this survey sample and the total study region population and illustrates the general representativeness of the sample. The percentages show that gender, age, and housing status of the survey respondents are quite similar to the population, while the educational status of participants in the survey sample is slightly more advanced than the study region population.

3.4. Analysis

Qualitative responses were assessed using a content analysis of the direct quotations to determine the frequency of response categories and trends in

Table III. Characteristics of Survey Respondents for Qualitative Analysis

Name	Gender	Age Group	Educational Status
Karen	Female	26–40	Graduate degree
Stan	Male	18–25	Some college
Sarah	Female	18–25	Graduate degree
Jim	Male	26–40	High school diploma
Dan	Male	18–25	Bachelor's degree
Mary	Female	41–55	Bachelor's degree
Paige	Female	56–70	Bachelor's degree
John	Male	18–25	Some college
Robert	Male	41–55	Graduate degree

response characteristics.[35] Analysis of the accuracy and trends within the 282 flash flood definitions was broken down by key word and a count of frequency was determined. In terms of characterizing rainfall associated with flash flood events, definitions with the words *heavy*, *excessive*, *intense*, *torrential*, *hard*, *downpour*, *severe*, and *a lot* were analyzed. For defining a time period of flash floods, the key words of *short*, *quick*, *sudden*, *rapid*, and *fast* were analyzed. Other key words that were analyzed to assess the amount of detail within provided definitions included: *river*, *stream*, *creek*, *banks*, *flood stage*, *dam*, *urban*, *road*, *bridge*, *sewer*, *rain*, *precipitation*, and *melt*. Flash flood risk characteristics were evaluated by tallying the number of times that a given attribute is mentioned within a respondent's list of risks.

A set of the respondent definitions was included to help illustrate characteristics of flash flood definitions. Each definition has a name attached to it that matches up with demographic characteristics for the respondent; these can be seen in Table III. Names associated with these quotes are fictitious to keep survey respondents anonymous.

Quantitative analysis of the responses for each question within this study was performed using the SPSS statistical program to evaluate response category percentages, cross-tabulations between variables, chi-squared tests, and demographic differences. A cross-tabulation is a contingency table that provides counts of the number of records within a database that fall within a given category defined by the intersection of two fields in that database. The chi-squared test compares the observed frequencies within this contingency table with the expected frequencies, given that a null hypothesis for the test is true, and is used to determine whether differences between observed and expected counts are too large to be caused by chance.[36] The statistical chi-square parameter is used within this analysis to measure the closeness between observed and expected frequencies. Small values of chi-square suggest acceptance of the null hypothesis, while large values that exceed the critical chi-square value for the degrees of freedom within the table and required probability of exceedance suggest rejection.[37] For this research, critical chi-square values correspond with the 0.05 probability of exceedance. One caveat with computing chi-square for a contingency table is that if 20% or more of the cells have expected counts less than 5, or if any expected count is less than 1, then the chi-square test may not always be accurate.[36]

4. QUALITATIVE RESULTS

4.1. Flash Flood Definition

The National Weather Service (NWS) provides the following official definition for a flash flood.[38]

> *A flood which is caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours. Also, at times a dam failure can cause a flash flood, depending on the type of dam and time period during which the break occurs.*

This definition was compared to the definition of survey respondents to determine the level of understanding of flash floods within the general public. Table IV contains the frequency of each word within the three categories of flash flood key words used to accomplish this comparison.

The most common word used to describe the intensity of rainfall that would lead to flash flood conditions was *heavy*, while there was more variety in word choice for the corresponding time period of flood onset. In terms of the source of flash flood development, rainfall key words were mentioned within 45% of the definitions, snow melt and dam failure were acknowledged as a source by less that 1% of the respondents, and the other 54% did not provide a source of excess water.

4.1.1. Rainfall

Only 92 of the definitions included at least one of the rainfall key words listed in Table IV, which means that 67% of the respondents did not include an accurate and descriptive representation of the rainfall needed to initiate flash flood conditions. For example, Karen defined a flash flood as:

> *A flood that occurs quickly due to a storm of some sort.*

Table IV. Frequency and Percentage of Key Words Within Survey Definitions for Flash Flood

Rainfall	Count	Percent	Time Period	Count	Percent	Characteristics	Count	Percent
Heavy	52	18.4	Quick	69	24.5	Rain	117	41.5
A lot	10	3.5	Sudden	53	18.8	Stream	77	27.3
Excessive	9	3.2	Rapid	51	18.1	River	75	26.6
Intense	7	2.5	Short	42	14.9	Creek	43	15.2
Hard	4	1.4	Fast	16	5.7	Banks	35	12.4
Downpour	4	1.4				Melt	13	4.6
Torrential	3	1.1				Road	11	3.9
Severe	3	1.1				Precipitation	10	3.5
						Flood stage	4	1.4
						Dam	4	1.4
						Bridge	2	0.7
						Sewer	1	0.4
						Urban	0	0
Total:	92		Total:	231		Total:	381	

$N = 282$, some respondents included multiple key words.

Even though this person understands the rapid rate at which flash floods can develop, she is unaware of the type of rainfall needed to initiate flood conditions. Another example of this lack of awareness of required rainfall rates can be seen in Stan's definition.

> *A flood that occurs when a stream or river overflows its banks and rapidly covers the surrounding and downstream area during or immediately after a rain.*

Definitions out of the sample that do include a rainfall attribute match the true definition very closely because the majority of them also accurately state the brief time period of floods. Sarah provides a good description of the necessary rainfall as:

> *When there is a lot of rain in a short amount of time and the ground cannot hold it all, rivers and streams swell and rise quickly and create a flooding situation.*

Jim also shows that he has an understanding of the required rainfall in his definition:

> *Short period of heavy rains that exceed the area's ability for drainage/absorbtion.*

4.1.2. Time Period

A total of 231 definitions provided at least one accurate time attribute of the flash flood process listed within Table IV, which reveals that 82% of the respondents are aware of the short timeframe. This high representation in knowledge of flash flood rates is excellent because rapid development and exposure is the most important aspect of flash flood awareness and safety. Dan emphasized the brief nature of these events as:

> *A rapid increase of water level, surpassing the defined flood level, caused by heavy precipitation or snow melt.*

Interestingly, only 14 respondents attempted to provide an exact unit of time to their definition. A total of 10 individuals stated that flash floods occurred on the order of hours and 4 said that the process occurred in a matter of minutes. Only 1 individual out of the 282 submissions included the six-hour defined threshold. One of the better time unit definitions came from Mary.

> *Water rising from streams or low-lying areas at a rate that puts property and human life at risk or danger or precludes preventive action due to the speed of water rise. For example, a 1–2 ft. rise over flood stage over a period of 2 or 3 days would not pose as much risk to property/life as a 1–2 ft. rise over a 4 hr. period.*

There is still a small portion of the general public that is not aware of the time period of flash floods. These individuals may understand that you need an extreme weather event to initiate the flood conditions, but they do not emphasize that this has to occur in a short time. Paige and John provide examples of this misunderstanding.

> *Spot flooding from heavy rain or runoff into small streams.*

> *A flood from heavy precipitation.*

4.1.3. Descriptive Words

From the other characteristic keywords in Table IV, it is clear that the general public is aware of rural flash flood events within floodplains of river and

Table V. Most Common Adverse Impacts Within Survey Results; $N = 282$

Adverse Impact	Count	Percent	Adverse Impact	Count	Percent
Property damage to house or car	115	40.8	Bridges impassable or washed away	15	5.3
Drowning	108	38.3	Erosion	14	5.0
Loss of life or injury	53	18.8	Loss of life or injury to animals or livestock	14	5.0
Swept away (car, house, or person falling)	52	18.4	Mudslides	13	4.6
Roads flooded or washed out	49	17.4	Electrocution	11	3.9
Stranded in car or house	26	9.2	Strength and speed of flood waters	11	3.9
Impacts of debris flow	23	8.2	Power outages	11	3.9
Contaminated water	15	5.3	Basement inundation	10	3.5

stream networks, but there was little mention of the fact that flash floods can also occur during dam failure and within urban areas. These results also show that there is a much higher awareness of rainfall-related events than flash floods induced by melting snow. Robert provided one of the best and most informative definitions out of the sample.

> *A faster, more dangerous flow of water that results from tropical storms, dam failures, or excessive rain and snow; the flooding of an area that occurs in a matter of hours.*

4.2. Flash Flood Hazards

The variety of responses provided regarding potential dangers during flash floods shows that people are making connections with some of the many adverse impacts and side effects that flash floods can generate. The information in Table V helps to illustrate that more people within the general public think about adverse impacts from floods that may directly affect their life and property than other adverse impacts.

Analyzing the frequency of occurrence reveals three groups of adverse impacts: the top tier (frequency >100) includes property damage and drowning; the second group (25–100) includes general injury or loss of life, impacts that the flood waters can have on roads, and getting caught in high waters in a car or the house; and the bottom tier (frequency < 25) is a mix of attributes that describe impacts and side effects of the flooding.

The wide variety of adverse impacts found within survey responses also help to reveal the broad level of vulnerability to danger that flash floods can pose on the general public. One important aspect of this broad awareness is that people who may not be directly affected by flash floods in their own household can be concerned about the potential effects of flood waters during travel time to and from work or wherever else they may be going. A respondent addressed this issue within a comment stating that:

> *Our risk of flash flooding is from a small creek that runs along the secondary road we travel, but we know how fast it rises, and when, in a rain event.*

5. QUANTITATIVE ANALYSIS

5.1. Knowledge

The first set of questions in the survey focused on factual information and was used to address the general understanding of flash floods. Response rates revealed that the general public is aware of the occurrence of flash floods within their region, as nearly 150 of the respondents stated that they remembered a flash flood in their community within the past two years. Only 12% of the respondents correctly identified the defined six-hour threshold of flash flood development, 25% knew that flash floods are the number one killer, 15% were aware that an overwhelming majority of all natural disasters involve flooding, 22% knew that it takes two feet of water to sweep a car away, and over 70% were aware that six inches of water can knock a person off their feet. The majority of the respondents underestimated the time period of flash floods and the amount of water required to pick up a car, which would increase caution.

Table VI provides chi-square values for these questions based on relevant demographic and behavioral categories. Results in this table suggest that the only variation in flash flood knowledge across public demographics and behaviors lies within the ranking of flash floods in terms of casualties. Men are more aware that flash floods rank number one in terms of weather-related deaths than women, while women perceive that flash floods are not as life threatening as other weather hazards. Also, older adults (ages 26–55 years) rank flash flood deaths more accurately, while young

Table VI. Chi-Square Tests for Knowledge Survey Questions (Bold: $p < 0.05$)

Question	Variable	*df*	Critical χ^2	χ^2	*p*	Cells < 5
Flash flood time threshold	Gender	2	5.991	5.399	0.067	0
	Age	4	9.488	3.452	0.485	1
	Flood experience	4	9.488	7.757	0.101	1
Flash flood rank, in terms of casualties	**Gender**	**2**	**5.991**	**8.170**	**0.017**	**0**
	Age	**4**	**9.488**	**11.860**	**0.018**	**0**
	Flood experience	4	9.488	5.305	0.257	1
Flash flood as percentage of natural disasters	Gender	3	7.815	0.153	0.985	0
	Age	6	12.592	11.381	0.077	0
	Flood experience	6	12.592	6.721	0.347	2
Critical depth—car	Gender	2	5.991	0.738	0.691	0
	Age	4	9.488	4.531	0.339	2
	Flood experience	4	9.488	0.792	0.940	2
	Risk to life	4	9.488	7.033	0.134	2
Critical depth—person	Gender	2	5.991	1.155	0.561	0
	Age	4	9.488	4.155	0.385	2
	Flood experience	4	9.488	1.285	0.864	1
	Risk to life	4	9.488	7.037	0.132	3

adults (ages 18–25 years) underestimate the ranking the most. This would translate into young adults having the lowest awareness of a flash flood's risk to their life. Frequency of previous experience in flash floods and sense of personal risk did not affect an individual's understanding of any of the flash-flood-related facts.

5.2. Interaction with Flash Floods

Table VII provides chi-square values for questions based on the public's exposure and interaction with flash flood events in the past as related to relevant demographic and behavioral categories. Respondents do not feel that flash floods affect them frequently, and the majority of the respondents stated that they consider flash floods to be a low risk to their life and property. A direct comparison between the general public's response to their perceived risk of flash floods to their life and property reveals a higher concern of impacts to one's life than to personal property. Frequency of exposure to flash floods in the past affects the perception of adverse impacts as well, as increased experience with flooding raises the general perceived danger for an individual. Repetitive occurrence of flooding events within a short time period can also dramatically increase the awareness of the general public, as was the case with Hurricane Frances and Hurricane Jeanne in the fall of 2004. One survey respondent reinforced this within a comment by stating the following.

> *I live on Craig's Creek in Botetourt [County, Virginia] and in my naiveté, was somewhat misled about how common flooding was here. Hurricane season 2004, and most specifically Jeanne, cured us of that.*

Housing status and location in relation to floodplains impact perceived risk to property but not perceived risk to life. Direct impact to personal property is not the only mechanism that can increase awareness and concern. Witnessing the impact of flash floods to households nearby can also alter the perspective that an individual will have toward these events. Another comment emphasizes this notion.

> *I live next to the Roanoke River in SE Roanoke, but not in the floodplain. But I have seen the devastation and financial hardship that many of my neighbors have gone through in the past few years due to the flooding of the river.*

Results from this survey show a slightly higher concern for property damage among renters than homeowners, although rental property owners did not express a heightened sense of adverse impacts toward their property. Over 90% of the respondents did say that they would consider whether a house is within a floodplain before a purchase. Finally, results reveal that there is no difference in how often people

Table VII. Chi-Square Tests for Interaction Survey Questions (Bold: $p < 0.05$)

Question	Variable	*df*	Critical χ^2	χ^2	*p*	Cells < 5
Risk to life	Gender	2	5.991	4.537	0.102	0
	Age	4	9.488	4.969	0.290	2
	Flood experience	**4**	**9.488**	**54.351**	**0.000**	**1**
	Risk to property	**4**	**9.488**	**51.065**	**0.000**	**1**
Risk to property	Gender	2	5.991	3.107	0.212	0
	Housing status	**4**	**9.488**	**21.746**	**0.000**	**1**
	Rental property	2	5.991	3.941	0.139	1
	Floodplain	**4**	**9.488**	**58.560**	**0.000**	**2**
	Flood experience	**4**	**9.488**	**54.071**	**0.000**	**1**
Flood frequency	Gender	2	5.991	4.373	0.112	0
	Age	4	9.488	8.306	0.081	2
	Education	4	9.488	3.501	0.478	1

think they are impacted by floods between gender, age groups, or education levels.

5.3. Preparation

Questions of preparation were included within the survey in order to gauge how the general public monitors flash-flood-related weather events, their awareness of flash flood guidance (FFG), and where they look for their information. FFG characterizes the amount of rainfall required in a given time duration for flash flood conditions to become imminent over a given drainage area. Survey responses show that an overwhelming majority of the general public monitors the weather on a daily basis, as 35% of the respondents said they would check the weather once a day and 49% said they check more than once. Also, 76% of the respondents stated that they would track flash floods if they became a threat for a given day. The most common sources for retrieving weather data and warnings were the local news, the Weather Channel, and the NWS. There was no consensus in an exact expected warning time and threat area, but 80% stated that they wanted the warning at or within an hour of the flooding onset and 77% would prefer a more detailed target area than the current countywide warning extent.

Table VIII provides chi-square values for these questions based on relevant demographic and behavioral categories, and reveals many interesting findings about preparation actions within the general public. The survey results indicate that adults track flash floods more than those aged 56 years and over and young adults, with young adults showing the least interest in monitoring imminent dangers. Experience from previous flash floods and perceived risk to life do increase the frequency with which the public tracks flash flood events. Out of the provided warning sources, results suggest that women tend to look to the local news for warning information more than men, while men were more likely to utilize the NWS. The timeframe that an individual believed flash flood development to occur within dictated the amount of warning time they expected to receive. Also, increased vulnerability to flash flood events caused an individual to request a longer lead time for the warning. Knowledge and awareness of FFG was not influenced by any demographic or behavior. With only 6% of the respondents stating that they knew of FFG and what it means, it is clear that the general public as a whole is unaware of the beneficial information that FFG can provide for preparation and anticipation of flash flood onset.

5.4. Reaction

The final section of this survey addresses how the general public reacts when flash flood conditions become imminent and where they rate flash floods within the spectrum of weather-related natural disasters. Table IX provides chi-square values for these questions based on relevant demographic and behavioral categories.

Most people responded that they take a flash flood watch as "somewhat serious," while the majority of the responses regarding warnings were in the "serious" category. Attention to an issued flash flood watch or warning varies by age group, as young adults

Table VIII. Chi-Square Tests for Preparation Survey Questions (Bold: $p < 0.05$)

Question	Variable	*df*	Critical χ^2	χ^2	*p*	Cells < 5
Warning source	Gender	5	11.070	11.060	0.050	0
	Age	10	18.307	14.058	0.170	5
	Track flash floods	5	11.070	10.191	0.070	1
Track flash floods	Gender	1	3.841	0.267	0.605	0
	Age	**2**	**5.991**	**11.878**	**0.003**	**0**
	Flood experience	**2**	**5.991**	**10.601**	**0.005**	**0**
	Risk to life	**2**	**5.991**	**11.660**	**0.003**	**0**
	Risk to property	2	5.991	4.219	0.121	0
Lead time	Gender	4	9.488	3.228	0.520	0
	Housing status	8	15.507	5.772	0.673	4
	Flood experience	**8**	**15.507**	**21.220**	**0.007**	**3**
	Flash flood time	**8**	**15.507**	**18.651**	**0.017**	**3**
Warning area	Gender	3	7.815	6.524	0.089	0
	Housing status	6	12.592	3.229	0.780	4
	Flood experience	6	12.592	8.183	0.225	0
	Flash flood time	6	12.592	3.494	0.745	0
FFG knowledge	Gender	1	3.841	0.613	0.434	0
	Age	2	5.991	0.143	0.931	2

do not take these statements as seriously as adults and the elderly. Increased experiences from past events and higher perceived risk to life do cause people to pay more attention to watches and warnings. An assessment of the level of concern for a set of weather disasters (flash floods, high winds, hurricanes or tropical storms, severe thunderstorms, tornadoes, and winter weather, which have all affected the study region in the past) revealed that the general public has the highest concern for tornadoes, with the average response for flash floods being fourth out of the six events. An important point is that flash floods can develop within many of the other disaster events as well. One respondent acknowledged this important connection.

> *Since flash floods usually occur during other large events, I was glad you asked the question about tornadoes and hurricanes.*

Results within the severe weather ranking question do reveal that higher concern for property damage from flash floods results in a higher ranking for flash floods and hurricanes, which generate the most widespread damage of the disasters. There also is a relationship between whether an individual tracks flash floods and his or her resulting concerns, as people who routinely track events tend to rank flash floods and severe thunderstorms higher than those who do not. Overall, results suggest that even though flash floods are a common occurrence within natural disasters, are the deadliest weather-related disaster, and generate billions of dollars in damage a year, the general public does not have as high of a concern for flash floods directly as they do for other disasters.

6. CONCLUSIONS

6.1. Discussion

This study provides some key conclusions about the perception and awareness of flash floods, and preparation trends in southwest Virginia. In spite of an abundance of studies seeking to evaluate risk perceptions of the general public as related to natural disasters and flash floods, there is a lack of information on the issue within flood-prone regions of the southeastern United States, and this research fills that gap while contributing to the general body of literature on risk perception. The results reveal that a knowledge base of flash floods does exist, but is not advanced enough for proper awareness and needs improvement. There is a clear understanding of the short timeframe associated with flash flood development, but knowledge of the required weather mechanisms and hydrological process that lead to the flood is not as strong. The general public grasps the notion of flash flood occurrence within rural floodplains along rivers and streams, but there was little mention of the fact that these flood waters can rise within urban areas,

Table IX. Chi-Square Tests for Reaction Survey Questions (Bold: $p < 0.05$)

Question	Variable	*df*	Critical χ^2	χ^2	*p*	Cells < 5
Watch severity	Gender	2	5.991	1.800	0.407	0
	Age	**4**	**9.488**	**27.667**	**0.000**	**2**
	Flood experience	**4**	**9.488**	**20.694**	**0.000**	**1**
	Risk to life	**4**	**9.488**	**21.272**	**0.000**	**1**
	Risk to property	4	9.488	4.173	0.383	1
Warning severity	Gender	2	5.991	1.619	0.445	2
	Age	**4**	**9.488**	**18.864**	**0.001**	**2**
	Flood experience	**4**	**9.488**	**14.082**	**0.007**	**2**
	Risk to life	**4**	**9.488**	**21.360**	**0.000**	**2**
	Risk to property	**4**	**9.488**	**11.136**	**0.025**	**3**
Top weather concern	Gender	5	11.070	3.607	0.607	0
	Risk to property	**10**	**18.307**	**22.003**	**0.015**	**3**
	Track flash floods	**5**	**11.070**	**22.263**	**0.000**	**0**

from dam failure, or from rapid snowmelt as well. This lack of understanding of the entire spectrum of flash flood sources can potentially result in greater impacts on public safety and property. These findings support Beyer's conclusion that a stated knowledge and understanding does not necessarily guarantee that the public will make the correct decisions at the time of the event because people may fail to account for a component of flooding that they do not fully understand.[13]

The immediate perceived dangers noted most often in association with these events are primarily risks to personal property and involuntarily getting placed in a life-threatening situation, which do support the conclusions drawn from Gruntfest *et al*'s study.[19] However, it should be noted that even though awareness of risk to property is greater, these results reveal that risk to life is the more important concern of the two. Young adults are not as concerned with flash flood impacts and do not take imminent danger as seriously as older adults. Past experience with flooding and perceived risk play a key role in shaping the way that a person will approach flash floods. The general public monitors the weather through many sources and tracks flash floods when they become a threat, but they are unaware of some of the key forecasting and communication tools available, like FFG and the National Oceanic and Atmospheric Administration (NOAA) Weather Radio. There is also a suggestion from the data that the current method of warning about flash floods and other severe weather events is not provided at an appropriate level of detail for effective communication of where and when the events will develop. These enhancements could complement the acknowledged public image that it is better to be overwarned. Key findings about the overall knowledge and reaction of the general public to flash floods will be considered in an FFG model that is currently under development, and should continue to be evaluated and considered by flood experts in the future.

6.2. Recommendations

The goal of this research was to utilize an online survey to determine the current state of flash-flood-related knowledge and characteristics for the general public in southwest Virginia. Conclusions and findings from this survey research are significant, but several limitations are present in the study. In order to more directly understand the public's perception of flash floods, further assessment of the results could be pursued through direct interaction with individuals through interviews. Also, this survey did not receive enough response from individuals who live near a floodplain or a flood-prone region, so future survey and interview studies of floods should target respondents who are at higher risk of being affected by floods. It is unfortunate that a catastrophic event like Hurricane Katrina is required to bolster public awareness, but it is also critical to continue monitoring the current state of flood awareness in the general public while images of the aftermath are fresh in people's minds.

While this research represents a case study of the public perception of flash floods in southwestern Virginia, the research illustrates that there is a knowledge gap between the risk understood by the public and the risk that public officials attempt to

communicate, and many of the conclusions can be generalized to other locations, such as communities attempting to improve communication of flood danger during hurricanes, for example. The understanding of flash flood awareness that comes from this research should be considered by flood experts as they address forecasting and communication issues because the findings can help to alleviate some of the breakdowns that exist with the public. Increasing knowledge and awareness of flash floods could be accomplished through training sessions, presentations at public functions, informational fliers, television public service announcements, promotion of the "turn around, don't drown" campaign, or the provision of more weather data sources and communication links for public use through various media outlets. Education of flash flood knowledge to the general public should focus on strengthening the understanding of what meteorological and hydrological processes lead to flood onset and how quickly different flash flood events can develop, increasing awareness of the warning sources available to track flash floods, and informing the public of the availability of key flood forecasting tools like radar and rainfall and streamflow data, as well as FFG. Lack of awareness and concern among young adults can be improved by offering educational functions at public schools and universities to school-aged children and young adults so that they can learn the dangers of flash floods and flash-flood-related weather events from an earlier age. Most importantly, the results presented here help bridge the knowledge gap that presently exists between flood experts and the general public and provide key clues in how flash flood forecasting and notification should be implemented.

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