BLIZZARD RISK, PERCEPTION, AND PREPAREDNESS IN THE NORTHERN GREAT PLAINS

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Abstract: With extreme weather events expected to increase as the planet warms, weather disasters and society's vulnerability to them are becoming more frequently studied. One of the weather hazards of most concern in the north-central United States is the blizzard. Blizzards are among the deadliest and costliest events in the United States, and the Northern Great Plains experience these events more frequently than anywhere else in the US. The purpose of the research presented in this dissertation is to apply existing knowledge to a hazard that is underrepresented in the literature. Previous studies on blizzards have mainly focused on climatological data, and the few that did include information on perception and preparedness did so using only quantitative survey questions, which do not allow the survey respondent to expand on their view points. For vulnerability analyses, much of the research is done at the county level though the research consistently argues that vulnerability is a more localized phenomenon. It may be better understood and provide more efficient resource allocation if studies are done at smaller geographic levels, such as the Census tract. Data for the snow seasons of 1950/51 through 2010/11 were used to determine the areas in the Northern Plains had highest exposure as well as which time of year is the most likely to experience blizzards. According to the seasonal exposure analysis, South Dakota experienced the most blizzards. The months of March and April combined (termed late-season) exhibited the highest exposure with the month of March showing the highest overall. Throughout the study period, a significant decreasing trend in the number of storms was observed. Multiple indices were calculated and compared at the tract level for one county within the study area, and surveys were also distributed to ascertain perception and preparedness in the two most active states using both open-ended and closed-ended questions. Through the use of surveys, it was found that the residents of North and South Dakota know what a blizzard entails and are highly prepared for such a storm. Little demographic difference was found in the open-ended questions, and this may be due to their experience with blizzards. Tract level analysis was done using a method previously published and created for county-level analysis by Miller, Johnson, and Dobson. Using variables from the 2010 U.S. Census and the 2008-2012 5-year American Community Survey, social vulnerability and resilience indices were calculated for the tracts of Cass County, North Dakota and then combined into quadrants. Three difference indices were calculated by switching the index in which the heating variables were included. Only three Census tracts changed: one in Fargo, and two larger rural tracts in the northern and western parts of the county. This suggests that the use of gas versus electric heat does not have much of an impact on blizzard vulnerability or resilience, except for those residents that live in more remote locations.

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CHAPTER I

INTRODUCTION TO THE RESEARCH

Introduction

People in the United States have taken scattered weather observations since the 1640s and instrumental bi-daily readings since the 1700s to evaluate impacts on crops and society (Fiebrich 2009). Over time, the network of both official and volunteer observing stations began to grow making it easier to track storms and their paths. More attention is usually paid to those storms that cause more damage and/or impact a larger area or population. When it comes to mapping and analyzing the spatial dynamics of these events, geography is the discipline at the forefront. Although, it is difficult to locate specific risk areas with some storms, such as blizzards. With more people and property moving into hazardous areas and improved spatial analytic tools, geographers are poised to make significant contributions to the understanding of spatial and temporal trends (Degg 1992; Montz and Tobin 2012). The type of storms of concern varies by geographic location. Those living along the Gulf Coast and the southeastern coast are likely to be more concerned with hurricanes than residents of the Great Plains where tornadoes and snowstorms are of bigger concern.

The characteristics that make a snowstorm severe depend on the part of the country under examination. For example, snowfall amounts of a few inches may be considered an inconvenience for those living in the Northeast but have the potential to shut down cities in the South for days. Because of these differences, a regional snowfall index (RSI) was developed that accounts for magnitude and frequency of snowfall events in each region, thus allowing for trend analyses of regionally severe snowfalls. Some research has shown that regionally severe snowstorms have doubled in the last 50 years compared to the previous 60 years (Kunkel et al. 2013) and the higher latitudes can be expected to see an increase in snowfall as the climate continues to change (Kapnick and Delworth 2013). Regional variations in factors influencing severity means a nationally standard definition of a snowstorm is not possible (Changnon and Kunkel 2006). The National Weather Service (NWS) and American Meteorological Society (AMS), however, do provide a standard definition for blizzards: winds of at least 30 knots (35 mph) and low visibility (less than a quarter mile) due to blowing or drifting snow for at least three hours (AMS Glossary). In a presentation at the 2015 annual meeting of the American Association of Geographers (AAG), Coleman, Schwartz, and Boren studied the frequency of blizzards at the county level for the contiguous United States for the seasons (October-May) of 1959/60 through 2013/14. They found that the Northern Plains exhibit the highest frequency and highest probability of blizzards with the months of November-April most active. January saw the most activity in this region with more than 20 blizzards recorded in the Dakotas. Despite an overall increase in frequency, the authors suggest the existence of a 12-14 year cycle of events (Coleman, Schwartz, and Boren 2015).

Calculating the frequency of disasters is one way in which exposure can be determined. If the event has happened frequently in the past, it is likely it will occur again. Risk, therefore, increases since risk is related the probability of occurrence (Short, Jr. 1984). Historically, risk analysis has been concerned with advancements in science and technology and potentially negative outcomes, focusing mostly on economic impacts and loss of life. What is lacking is the social and cultural aspects of risk and risk perception, although it is being included more frequently. Many factors can influence a person's perception of risk, including experience, knowledge of the hazard, and socioeconomic status (Short, Jr. 1984; Freudenburg 1993).

Research Questions

Severe snowstorms and blizzards are a common occurrence in the Northern Plains states, which could create complacency and increase vulnerability. Even in places where severe winter weather is common, a snowstorm can become a disaster (Smith 1992). However, the commonality of these storms can also increase resilience in that residents take necessary precautions and preparations in advance of the event. This study looks to determine blizzard exposure within the northern portion of the Great Plains (Figures 1.1 and 1.2) using storm data for the seasons of 1950/51 through 2010/11 and the months of October-April. In addition, the perception of risk and preparedness levels for two states in the study area will be ascertained as well as a more detailed analysis of social vulnerability (inability of people or societies to cope with and recover from disasters) for a county in one of the states.

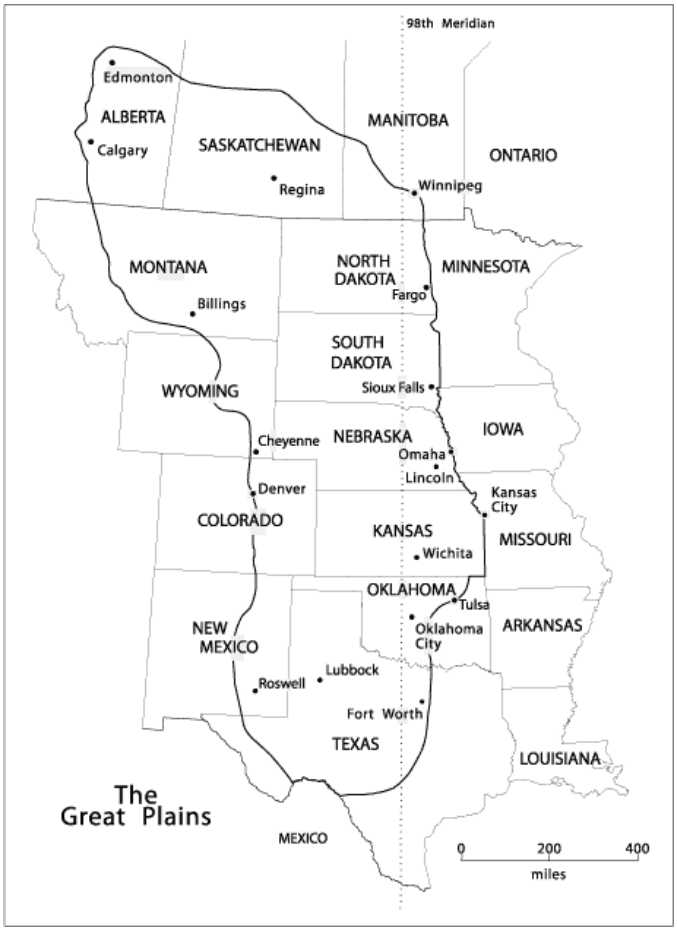

Figure 1.1: Boundary of the Great Plains according to Center for Great Plains Studies, obtained from http://www.unl.edu/plains/about/map.shtml

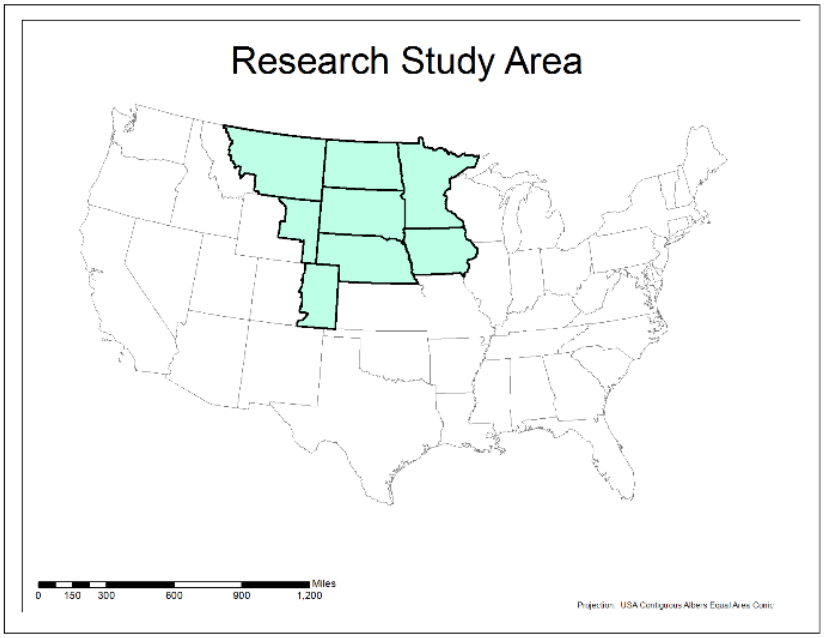

Figure 1.2: Research study area highlighted in blue

For this research, three main questions correspond to the idea of exposure and vulnerability to winter weather hazards.

1. What is the blizzard exposure in the United States Northern Plains during the snow season (October-April) for the years 1950/51-2010/11?
    a. What is the exposure for seasonal (December-February) versus non-seasonal (October-November and March-April)?
    b. Is there a difference in exposure between early-season blizzards (October-November) and late-season blizzards (March-April)?
    c. Which month(s) exhibit the highest exposure?
    d. Has there been a trend in the total number of blizzards? Have there been trends in seasonal storms, early-season storms, and late-season storms?
2. Previous research (Heise 2013) showed South Dakota and North Dakota to have similar risk with more frequent blizzards than the rest of the study area (Figure 1.2). How do people in these states perceive their risk for blizzards? How do they define a blizzard? How do they prepare for the winter season and for blizzards?
    a. Are there differences between various social groups (i.e. urban vs. rural, male vs. female, white vs. non-white, hazard professionals vs. non-professionals) in how risk is perceived and preparation?
    b. Will their perception of risk be lower than the calculated risk?
3. Previous research (Heise 2013) also showed Cass County, North Dakota to have low to average vulnerability at the county level. What is the spatial trend of social vulnerability at the tract level?

a. How does the inclusion of different variables change the results?

Question 1 was evaluated by collecting historical weather data for weather stations within the study area and mapping the subsequent counts. Surveys were used to collect the data for question 2 with coding and frequency statistics used for analysis. Census data and American Community Survey data centering on 2010 were used for the vulnerability analysis in the question 3. The exact methods are expanded upon later for each of the three articles that cover these questions.

Literature

Hazard, risk, and disaster research began with the Department of Defense during the Cold War as the U.S. military and U.S. government wanted to understand how people would react to wartime activities. However, Prince's work on the 1917 munitions explosion in Halifax is said to be one of the first systematic studies of disaster and vulnerability (Quarantelli 1987; Oliver and Hoffman 1999). Hazards threaten communities and the things they value, and they fall into one of three categories: meteorological (i.e. temperature extremes, hurricanes, blizzards), geological (i.e. earthquakes, landslides), or hydrological (i.e. floods, ENSO). If the event occurs and the affected community is unable to cope with the impacts, it becomes a disaster (Gregg and Houghton 2006).

Historically, hazards have been the purview of geography while sociology focused on disasters (Cutter 2001). Now, however, the research is increasingly interconnected and interdisciplinary. There has also been a shift in the paradigm used for hazards research. Initially, the idea was to map the hazard and the people in the hazard zone, determine the potential adjustments and perceptions of the affected population, and figure out the ideal

adjustments to mitigate loss. The new paradigm is largely the same, but the need for sociopolitical context has been added (Cutter 2001) because both the causes and consequences of a disaster stem from the social structure and social processes of the affected community (Kreps 1984). According to one study, more than half of the existing research in the field was produced between 1977 and 1997 and has been expanded to include the importance of the context of creation and vulnerability (Alexander 1997).

Hazards, when they occur, have the potential to quickly turn into disasters. The Disaster Relief Act (DRA50) passed in 1950, and it shifted the power to make disaster declarations from Congress to the President. The first such declaration was made by President Eisenhower in May 1953 following tornadoes in Georgia, and the number of declarations has risen each year since from an average of nineteen a year in the 1960s to sixty-seven a year (so far) in the 2010s. Since that first declaration in 1953, 2011 had the most with ninety-nine. This observed increase in declarations could be explained by any, or all, of the following factors: improvements in technology tracking the events, population and development increases, change in policy (i.e. FEMA changing their snow policy in 2009 to more closely align with a DRA50 amendment classifying snow events as disasters instead of emergencies), increased knowledge of the declaration process, a 24-hour news cycle, and the increase in professional emergency managers (Lindsay and McCarthy 2015).

The Federal Emergency Management Agency (FEMA) was created in 1978 by President Carter, and it became the central bureau for the distribution of federal disaster aid under the Stafford Act of 1988, an amendment to the DRA50. Following the terrorist attacks of 11 September 2001, FEMA became part of the Department of Homeland Security. The Stafford Act also created three declaration categories: fire management grants, emergency,

and major disaster. Emergency declarations, which included nearly all snow events up until 2009, have increased over the last twenty years. The first decade of the 21st Century averaged fifteen emergency declarations a year, compared to an average of nine a year from 1974-2014. Snow emergencies accounted for 26.2% of emergency declarations since 1953, making them the second most common emergency declaration behind hurricanes (27.8%). Within the Northern Plains, North Dakota received the most emergency declarations with nine (Lindsay and McCarthy 2015).

Switching to major disaster declarations in the Northern Plains, Iowa (fifty-five) has been given the most with Minnesota (fifty-two) and Nebraska (fifty-one) following behind. Snow accounts for 2.6% of all major disaster declarations issued since the passage of the DRA50 and the policy change in 2009. In 2013, there was another amendment granting tribes the ability to submit their declaration request for events within their lands. Before this amendment, any disasters that occurred on tribal lands required a petition to the governor for a portion of the state's federal aid. Since this amendment, seven disaster declarations have been granted for tribal lands. Six of those were granted the year the amendment passed, including one for flooding that affected the Standing Rock Sioux in the Dakotas. (Lindsay and McCarthy 2015).

In regards to winter storms, the Northern Plains saw more than $330 million in damages between 1950 and 1989 (Changnon and Changnon 1992). Winter storms have been shown to kill 30-40 people with an average of 3.7 catastrophic winter storms (defined as causing more than $1 million insured property loss) a year (Changnon 2007). Additionally, winter weather accounted for 18% of the hazard mortalities measured by the Spatial Hazard Event and Loss Database for the US (SHELDUS) from 1970-2004 (Borden and Cutter 2008).

Loss and death trends for these disasters, as well as trends in disaster frequency, are being seen more frequently in the literature. Thomas and Mitchell (2001) examined monetary loss and death from 1975-1998 in the United States. They found that New York, California, Texas, and Ohio are among the states with the most disaster deaths while Alabama and Mississippi showed the highest monetary loss for hazards in general as well as winter storms specifically. However, the results were based on the raw numbers per state instead of per capita, creating a bias towards the states with larger populations. When determining the most hazard prone states, they calculated the damages and fatalities per 100,000. By normalizing the data, North Dakota became the state with the highest economic loss. The normalized fatality data, though, showed a much different trend compared to the non-normalized results. Four of the states in the Northern Plains—Wyoming, Colorado, Montana, and North Dakota—are among the top ten states for disaster fatalities per 100,000 people (Thomas and Mitchell 2001). Despite the higher fatality rates, few states in the Northern Plains were among their list of most hazard-prone when taking into account the number of events, deaths, and damages, except Iowa which ranked ninth. Wyoming and Montana were among the ten least hazard prone states with South Dakota sitting at eleventh from the bottom (Thomas and Mitchell 2001).

According to Montz, Cross, and Cutter (2003), the main guiding research questions for the field have not really changed over time. However, they note that understanding them has grown to include: 1) the recognition of a continuum of classifications instead of the typical natural-technological binary, 2) the need for socio-political context, 3) the complexity of the issues, and 4) a shift towards total risk instead of focusing on a singular hazard. Total risk includes understanding perception and preparedness in addition to the environment.

As was argued by Weichelgartner (2001), preparedness, which is any action taken to minimize loss, is one of the key components to understanding social vulnerability. He goes on to say that the perception of risk is one of the things taken into account when deciding how, or if, to prepare. In the early years, studies on risk perception, done mainly by geographers, focused on weather hazards such as flooding, drought, and tornadoes and showed that people in the communities do know how to reduce their losses. However, it is experience with the hazard along with socioeconomic factors that determine if they actually take those actions or how much of a threat they perceive it to be (Kreps 1984; Cutter 2001; Gierlach, Belsher, and Beutler 2010). In an article on blizzard preparations in Ohio in January 1978, it was shown that societies may become complacent when events take place in rapid temporal succession (Neal, Perry Jr., and Hawkins 1982). This complacency may lead to people not preparing as they would when the storms are more spread apart through time, and inadequate preparation and complacency may increase social vulnerability.

Perception has also been tied to the concept of place attachment. Place attachment, or sense of place, is the connection a person has with their environment and has been applied to disaster studies in the past in regards to forced relocation (i.e. evacuations) and the impact on environmental perceptions. The idea of place attachment was first mentioned more than forty years ago, and many studies have found that people become attached to places even if they are shown to be a high risk area. Many factors can influence this attachment: diversity, number and type of services, social capital, education, and length of time in the area. Length of time, though, has been shown to be one of the strongest indicators of attachment (Vorkinn and Riese 2001; Scannell and Gifford 2010; Lewicka 2011; Cresswell 2013).

Scannell and Gifford (2010) argue that place attachment can serve many functions. One of these is for security and survival in which the resources of the place become the most important. If these resources help advance the person's goals, it also serves the purpose of support and self-regulation. The final function Scannell and Gifford discussed was continuity or stability. For many rural places such as the Northern Plains, land is kept in the family for generations and thus people may become strongly attached to the land, continuing to pass it down through the family. The authors also suggest that strong place attachment may lead to behaviors to improve their community (Scannell and Gifford 2010). In a study of potential hydropower developments in Norway, Vorkinn and Riese (2001) found that stronger place attachment lead to more opposition to the development project and place attachment was a stronger control of this opposition than the sociodemographic variables.

The idea of place attachment and desire to improve the environment may be applied to quantitative studies of hazards and disasters. Ritchie, Gill, and Long (2015) developed a concept known as homeplace to do this. Homeplace takes the amount of time a person has lived in the area and divides that by their age, resulting in a value between zero and one. Values closer to one indicate more of the life spent in the same area. As mentioned earlier, length of time is one of the most important controls of place attachment. In terms of disasters, this may also mean stronger bonds with members of the community, more involvement in the community, and increased knowledge of the events and resources available. This may then translate into increased resilience for longer term residents relative to newer residents.

The way in which people react and behave when it comes to risks and disasters can depend on factors other than experience and perception. Some argue that the main difference

between the two is the time scale: disaster behavior is focused on past actions and events while risk behavior is focused on a potential and uncertain future. Actions taken are based on past experiences that a person is trying to prevent from happening again (Stallings 1997). Various theories about behavior can be used to explain how and why people make the decisions they do. Two of these are resource mobilization and chaos theory.

Resource mobilization is the securing of control over a resource needed for collective action, which in the case of a disaster could be search and rescue, recovery, or reconstruction. Which resources are significant is not universal, but the need for outside contributions and the cooperation of institutions is significant. While some argue that the collective interests driving mobilization exist prior to the need for mobilization, others claim these interests are emergent, developing in the moment (Jenkins 1983). However, it is possible that both sides are correct and there are both pre-existing and emergent interests driving mobilization. Much of the research on resource mobilization has been done in regards to social movements, where a common cause or grievance brings people together to fight for the reduction of that grievance. It is through this research that researchers also come to realize that help from groups outside of the movement is also an important component. However, the resources available for use are constrained by a number of things, such as pre-existing system conditions, competition for access, transportation, media attention, and those in control of the needed resource (McCarthy and Zald 1977).

Although the literature on resource mobilization usually refers to social movements, the same ideas can be applied to disasters. Disasters impact entire communities and can create a collective trauma (Kaniasty and Norris 1995), and this trauma could be viewed as the collective interest through which the community comes together to collect the necessary

resources for rebuilding. One such resource may be seen as support from your neighbors. Kaniasty and Norris (1995) used these ideas to examine the mobilization and loss of social support after a natural disaster and the impacts on post-disaster stress using two case studies: Hurricane Hugo and Kentucky flooding. Support is measured as either received, perceived (it is there if needed), or socially embedded (how many relationships exist and their type). The received support could be viewed as the mobilization of the resources. However, the support and aid provided are generally unevenly distributed, with those most impacted receiving priority. They also found that characteristics such as sex, age, and education also determine who receives support and who does not. Educated white males were more likely to receive support than minorities and the poor (pattern of neglect). When it came to age, the elderly were more likely to receive support if their health was at risk (pattern of concern). Although, if this concern did not exist, they were more likely to fall victim to the pattern of neglect. If the perceived support does not materialize into received support (the resource isn't mobilized), the impacted communities are more likely to experience higher levels of stress (Kaniasty and Norris 1995).

The second theory that may explain disaster behavior is chaos theory. This is the idea that events do not follow a linear path and cannot be predicted using conventional cause-and-effect methods. Systems that are considered chaotic can reorganize and renew themselves, and they exhibit periods of stability that are broken up through sudden and irreversible events brought about by chance, such as a disaster. The changes to the system are unpredictable, but they are bounded. Another issue with chaotic systems is that focus on one singular event within the entire system can lead to misleading information because a single event cannot show the entire picture (Murphy 1996). Choosing different events within the same system

has the potential to lead to a much different interpretation or understanding of the system depending on which event was chosen as the focus of study. Using chaos theory for issue or crisis management, the goal is to discover the trends in the system to try to prevent them from reaching the tipping point. An example of a chaotic system is public opinion (Murphy 1996), such as attitudes and perception of risk.

While all pieces and potential outcomes of the system cannot be accounted for, qualitative methods, such as surveys, can become more important when trying to study chaotic systems. These surveys can be utilized as a simulation to better understand the system, but one must always remember that the simulation will likely not exactly predict the actual outcomes. Examples of chaotic systems include crisis behavior and decision making (Gregersen and Sailer 1993), both of which can be related back to disasters (crisis) and disaster mitigation (decision making). When making decisions to try to reduce the impacts of a disaster, there are many aspects that remain uncertain. Possibly the most important is the outcome of the action. Although the aim of mitigation is usually to remove the negative outcomes, the actions taken may actually lead to unintended negative consequences. For example, evacuation orders are given to try to move the population out of harm's way. Everyone leaving at the same time, however, can cause traffic to back up and no one is able to get out in time. Another example is the sending of food to help those who are suffering from famine, but an overabundance of food being sent may hinder the recovery as people may leave the food they are growing to go stand in line for aid and may make them more dependent on outside help (Bogard 1988).

In an article using Hurricane Katrina to show the implications of chaos theory on organizational development, Piotrowski (2006) argued that the disruption and organization

dysfunction following Katrina could be explained using chaos theory. By this, he means that the main tenet of chaos theory shows that apparent dysfunction and disarray are normal when systems have to adapt to high-stress situations, like what was seen in New Orleans following Katrina. Human behavior and response to stress are highly unpredictable and hard to control, making organizational disaster management planning more difficult. In addition, the disaster can expose problems that were not previously known that will also need attention or create new issues between the new needs of the community and their government (Piotrowski 2006). These emergent issues cause a disruption to the system that must be adapted to in order to return the system to normal.

These behaviors, however they are influenced, become part of the process that determine how vulnerable a community is to disaster. Vulnerability science, according to Cutter (2003), grew out of cross-disciplinary work and needs to continue to bring together the social and physical sides of the natural system. Social vulnerability began to become a larger focus in disaster research in the last half of the 1990s and continues to dominate the field (Montz, Cross, and Cutter 2003), and some argue that social vulnerability is the key to understanding and reducing risk. However, the researcher must remember that social vulnerability is dynamic and depends on the geographic scale with the ultimate goal to find the points in the system that need the most attention (Birkmann 2006a,2006b; Queste and Lauwe 2006).

The use of indicators to measure certain parameters, such as social vulnerability, has been done since the 1960s, and it is common to combine them into something known as a composite indicator. In disaster research, the most commonly used composite indicator is the Social Vulnerability Index (SoVI), which used factor analysis to create a measure of social

vulnerability that can be used at both the national and subnational level in any country (Cutter, Boruff, and Shirley 2003; Cutter et al 2008; Cutter, Burton, and Emrich 2010; Tate 2012, 2013). Many variables can increase an area's social vulnerability to disaster. The most commonly used are socioeconomic variables like those measured by the U.S. Census or American Community Survey: age, sex, employment (rate and type), race/ethnicity, income, education, vehicle ownership, utilities, age of home, home value, household size, language, etc. Other variables of interest often found in the literature on vulnerability assessment are roads, voting history, per capita services (i.e. hospitals, nursing homes), population growth, infrastructure, and urban-rural divides (Morrow 1999; Cutter, Boruff, and Shirley 2003; Buckle 2006; Cutter and Emrich 2006; Borden et al. 2007; Cutter et al. 2008; Yoon 2012). However, most studies of vulnerability are done at the county level despite the consensus that it is a more localized phenomenon.

Significance and Importance

As mentioned previously, there are many factors that influence vulnerability. It has been suggested that the rise in the global population and advances in technology are the reasons for the increasing number of disasters worldwide (White et al. 2001), and vulnerability has been listed as one of the big questions that geographers should be addressing as it is rooted in geography (Cutter, Golledge, and Graf 2002). Also of concern is the likelihood of more frequent extreme events with continued climate change (White et al. 2001; Gutowski, Jr. et al. 2008; Lein et al. 2009; Cuevas 2011). The rise in extreme events also carries the risk of amplifying factors of individual vulnerabilities such as poverty and hunger (Cuevas 2011).

Attempts to better understand extreme events can be done through studies of disaster risk or hazard vulnerability studies. Hurricanes, floods, and tornadoes are the most common topics of hazard research while winter weather is often overlooked. Research carried out on blizzard risk and frequency is often focused at the county level, potentially masking more localized trends in snow events. As with many weather hazards, these storms are not uniformly experienced throughout the county, and sometimes not even throughout the same city, so using county level warning data may not be accurate for the entire county. By using point data to create an interpolated surface, as is proposed for this dissertation, the differences across counties may be seen and has the potential to provide a better understanding of the risk. It also adds to the work on a hazard that is not mentioned as frequently in the literature as warm season hazards.

Recent research by Cutter, Ash, and Emrich (2014) on county level resilience has shown the Northern Plains to have among the highest overall levels of resilience (ability of a society to cope with and adapt to stresses on the system without long-term impacts). While resilience is not necessarily the opposite of vulnerability, places that show high resilience do tend to also show lower levels of vulnerability (Cutter, Ash, and Emrich 2014). This can be seen by comparing the vulnerability results from previous work (Heise 2013) with work by Cutter, Ash, and Emrich (2014). Locations in their work that show high levels of resilience are shown to have lower vulnerability compared to Heise (2013). However, this previous work on blizzard frequency was all completed at the county level which may hide pockets of higher or lower vulnerability that may be found at smaller geographic areas such as the Census tract.

Understanding the perception of risk in the community makes the differences between groups, judgment biases, and estimation errors clearer (Cutter 2001). By adding the perception of the risk to the understanding of the physical risk, a more thorough understanding of a community's social vulnerability may be achieved (Tobin and Montz 2009). It has also been argued that risk assessments should include the thoughts and perceptions of those affected by the hazard (Cutter 2001) because information outside of the socioeconomic data is needed to assess vulnerability and resilience (Buckle 2006). Social vulnerability cannot be fully understood by analyzing static socioeconomic and demographic variables alone, and the knowledge of the risk perception and preparation levels of the people may help local emergency managers see where to allocate resources or improve mitigation measures to better serve their communities. Schwartz (2000) included a perception component to his work creating a blizzard climatology, and he found that people had a generally accurate idea of what constituted a blizzard. However, the survey consisted of only closed-ended questions in which the respondents had a list of choices to use when giving their ideas of what makes a blizzard. This was justified by showing that fewer people had included a wind or temperature component on the open-ended survey options in his pilot study. By including options instead of leaving the questions open, his survey may have introduced bias thus over-estimating the accuracy of their perceptions.

Because numbers are generally the language of business and policy, finding a way to quantify perception, preparedness, and other variables not found on the U.S. Census has the potential to increase the robustness and applicability of vulnerability indices. If planners and policy makers have a measure of social vulnerability, a more structured analysis of inequality

can be done, and resources can be focused where they are needed the most (de Oliveria Mendes 2009).

The work in the following three chapters was designed to identify smaller patterns of risk and social vulnerability that may be hidden in previous research that used county-level units of analysis. While the use of point data in this particular case likely underestimated the true exposure, the surface created from this data provides some nuance to the larger patterns that are not possible with county level data. The survey article was designed to show that allowing respondents to freely and openly answer questions about perceptions and preparation may provide a clearer understanding of their needs. The final article on social vulnerability and resilience modifies an existing method to show that these phenomena are more localized. Using census tracts can provide more detail on where the most vulnerable populations are living, and thus where mitigation and aid strategies should be focused. By looking at the more localized spatial distributions, it becomes possible for hazards to have less of an impact and maybe not result in disasters.

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CHAPTER II

BLIZZARD EXPOSURE IN THE NORTHERN PLAINS USING DAILY WEATHER MAPS

Authorship and Journals

The title of this chapter, "Blizzard Exposure in the Northern Plains Using Daily Weather Maps," is the planned title for this article, and I propose to co-author with Dr. Stadler with myself as lead author. Because the research for this article focuses on mapping the exposure of a meteorological hazard, a journal through the American Meteorological Society (AMS) or specifically dedicated to risk would be chosen. Potential journals for publication of this article would be the *Journal of Applied Meteorology and Climatology* (JAMC) or *Weather, Climate, and Society* (WCAS). Both of these are AMS journals that publish articles relating to the interaction of society and the environment. The JAMC description includes climate risk and vulnerability among the topics covered, while the main focus of WCAS is the interaction of weather with society. Another potential journal would be *Risk Analysis*, which is a journal by the Society for Risk Analysis that has published articles on risk assessment and perception.

Abstract

With blizzards more frequent in the Northern Plains than anywhere else in the United States, this region is the focus of the current study. Although blizzards are often not uniformly experienced throughout the county, blizzard climatology studies are typically done at the county level. This can hide the banding that is possible with heavy snow and blizzard events. For this article, daily weather maps were used to count the number of days first-order weather stations reported blizzard conditions for the months of October through April in the seasons 1950/1951 through 2010/2011. The station totals were then mapped using inverse distance weighting interpolation to determine which areas were most exposed to blizzards. Using this method, it was found that South Dakota experiences the most blizzards with eastern North Dakota and western Nebraska also exhibiting a higher activity: all areas frequently in the path of winter midlatitude cyclones and Alberta Clippers. March was the most active month, and the late-season storm days (March and April) accounted for half of all recorded days during the sixty-one year period. January experienced the second highest frequency for blizzard days. A significant decrease in the number of events was found in both the decadal and yearly analyses. However, this decreasing trend was not significant for non-seasonal (October-November and March-April) events. By using sub-county scale data, this study was able to highlight the more localized patterns that may be hidden in county level analyses while providing the same generalized exposure trends found at the county level.

1. Introduction

Interest in storm patterns in the United States dates back to the 1640s when the first observations were recorded. The move toward studying how weather can impact

society began in the 18th Century with the introduction of instrumental readings (Fiebrich 2009). As the number of observers began to grow, storms and storm paths became easier to follow. However, more attention was usually given to the more destructive storms or those that affected a large number of people. The type of storms causing the most concern varied by location and time of year, such as hurricanes along the Gulf Coast or blizzards in the Great Plains.

When it comes to analyzing spatial extent, it can be difficult to find specific areas where the exposure is spatially extensive. A general area is all that can be determined. People and property are increasing in hazardous areas, and spatial analysis tools have improved. Using these new tools, spatial and temporal trends of the storm exposure for an area can be examined to get a better understand of the hazard risk (Degg 1992; Montz and Tobin 2012). However, most studies of blizzard exposure are done at the county level even though banding is common with some snow events. Blizzards are also an underrepresented hazard in the current literature. The purpose of this research is to determine if the same patterns found in previous blizzard climatology research can be replicated using a different method.

Hazards are natural events that threaten communities and the things they value, and they can be either meteorological (i.e. temperature extremes, hurricanes, blizzards), geological (i.e. earthquakes, landslides), or hydrological (i.e. floods, ENSO). When they occur, hazards can become disasters if the community is overwhelmed and unable to cope with the impacts of the event (Gregg and Houghton 2006). When this occurs, federal assistance may be requested. In 1950, the Disaster Relief Act (DRA50) was passed providing the U.S. President the ability to decide whether or not to offer federal aid to

areas affected by disasters without Congressional deliberation. The first such disaster declaration was made by President Eisenhower in May 1953 following a Georgia tornado, and the number has risen each year since. 1960 through 1969 saw an average of nineteen declarations a year, and 2010-2014 averaged sixty-seven a year. Since that first declaration in 1953, 2011 had the most declarations with ninety-nine. The observed increase in disaster declarations has many potential influencing factors: improvements in technology tracking the events, population and development increases, increased knowledge of the declaration process, the advent of a 24-hour news cycle, and the increase in professional emergency managers (Lindsay and McCarthy 2015).

Under the Stafford Act of 1988, the coordination of federal aid became centralized through the Federal Emergency Management Agency (FEMA), created by President Carter in 1978 and made part of the Department of Homeland Security following the terrorist attacks of 11 September 2001. The Stafford Act further provides categories of declaration: fire management grants, emergency, or major disaster. Emergency declarations, which included snow events until 2009, have increased over the last twenty years. While there was an average of nine a year over the period 1974-2014, the 1990s averaged six per year and fifteen a year for 2000-2009.

Snow emergencies were the second most frequent type of declaration, accounting for 26.2% since 1953. Within the Northern Plains, North Dakota recorded the most emergency declarations with nine, followed by Minnesota and Colorado (five each), Iowa (four), Nebraska (three) and Montana, Wyoming, South Dakota (two each). In regards to major disaster declarations, Iowa (fifty-five) has been given the most with Minnesota (fifty-two) and Nebraska (fifty-one) granted the second and third most declarations,

followed by North Dakota (forty-six), South Dakota (forty-four), Montana (twenty-four), Colorado (twenty), and Wyoming (nine).

In 2013, another amendment to the DRA50 was passed granting tribes the ability to submit their own requests for declarations for events within their land. Prior to this amendment, they had to petition the governor's office to receive a portion of the state's aid. Since this amendment passed, seven disaster declarations have been granted to tribal nations. Six were granted the year the amendment passed, including one for flooding in the Standing Rock Reservation of the Dakotas (Lindsay and McCarthy 2015).

Disaster loss and casualty trends, as well as trends in frequency, are being increasingly discussed in the literature. Smith and Katz (2013) found disasters increasing in frequency, but changes in population, property, and development are not taken into account. Thomas and Mitchell (2001) examined monetary loss and death from disasters for 1975-1998 in the United States, finding North Dakota experienced the highest monetary losses per 100,000 residents (Thomas and Mitchell 2001). Globally, the United States is second to China in the number of disasters during the last decade, and the United States experienced twenty disasters in 2014 causing $16.8 billion in damages (Guha-Sapir et al. 2015). In 2015, twenty-two disasters were reported in the United States causing nearly $24.9 billion in damages (CRED 2016).

In regards to winter storms, more than $330 million in damages were caused in the Northern Plains between 1950 and 1989 (Changnon and Changnon 1992). They kill between thirty and forty people a year with an average of 3.7 catastrophic winter storms (storms causing more than $1 million insured property loss) each year (Changnon 2007). Additionally, winter weather events accounted for 18% of hazard mortality as measured

by the Spatial Hazard Event and Loss Database for the US (SHELDUS) from 1970-2004 (Borden and Cutter 2008). Between 1980 and 2011, ten winter storms accounted for 7.5% of all billion-dollar disasters and 3.3% of the damages with $29.3 billion total damages in the United States (Smith and Katz 2013).

What makes a snowstorm severe depends on the part of the country the storm hits. For example, snowfall amounts of a few inches may be considered an inconvenience for those living in the Northern Plains but have the potential to shut down Southern cities for days. Understanding these differences and realizing that much of the impact from winter weather is on transportation, Rooney (1967) analyzed what he called the urban snow hazard in terms of this disruption. Using seven cities spread across the North Central U.S., he created a hierarchy of disruption ranging from one (paralyzing) to five (minimal), largely based on impacts to transportation and other services such as schools and power. His work found that Rapid City, South Dakota and cities in the Midwest are more likely to experience more disruptive storms, and the level of disruption increases with the amount of snow as well as the rate of snowfall and wind speeds. It was also shown that the combination of high snowfall amounts with strong winds (potential blizzard conditions) are more likely to produce the paralyzing conditions (Rooney 1967).

More recently, the NWS has been developing indices that would take these differential impacts into account. One such measure is the Winter Storm Severity Index (WSSI). The WSSI combines NWS gridded forecasts with data such as population and land-use in an effort to forecast potential impacts from winter weather (Nash and Soroka 2016). Another is the Local Winter Storm Scale (LWSS), which measures the potential for impact by placing the storm in historical regional context (Cerruti n.d.). The final

index being developed by the NWS is based on Rooney's disruption study, and it is known as the Rooney Disruption Index (RDI). The purpose of the RDI is to measure the actual disruption caused to services such as transportation, schools, power, and manufacturing to show the societal impacts from the event (Cerruti n.d.). These three indices, though, are designed for forecaster use only. Squires et al. (2014) also developed a measure known as the Regional Snowfall Index (RSI), which uses magnitude and frequency to provide a comparable statistic for studies of regionally severe snow events.

Some studies have shown that regionally severe snowstorms have doubled the last 50 years compared to the previous 60 years (Kunkel et al. 2013), and higher latitudes can be expected to see more snowfall in a continually warming climate (Kapnick and Delworth 2013). These regional variations in what influences severity means a standardized definition of severe snowstorm is not possible (Changnon and Kunkel 2006). The National Weather Service (NWS) and American Meteorological Society (AMS) do, however, provide a definition of blizzard that applies to all locations.

In a 2015 presentation, Coleman et al. discussed the frequency of blizzards at the county level for the contiguous United States for the months of October through May from 1959/1960 to 2013/2014. They showed the Northern Plains had a higher number and highest probability for blizzards, and November to April were the months with the most activity. January was the most active month for the area with more than 20 blizzards recorded in North and South Dakota combined. An overall increase in frequency over the study period was also found (Coleman et al. 2015). Also using county-level data, other studies found North Dakota, South Dakota and western Minnesota experiencing the most blizzards dating back to 1959. January, February, and

April were the months with the highest frequency, and the number of storms has increased (Schwartz 2000; Schwartz and Schmidlin 2002; Coleman et al. 2015). However, county level data may hide the smaller geographic scales in which events like snowstorms and blizzards are likely experienced.

Common to the Northern Plains and Midwest states, Alberta Clippers are among the most significant winter weather patterns, generally peaking in frequency during December and January while October and March experience the fewest during the snow season (Thomas and Martin 2007). Once these systems reach the Plains, new fronts can form, or the existing system could deepen/strengthen (Schultz and Doswell 2000), thus allowing for blizzard conditions to potentially develop. The conditions of a Clipper system may occur over smaller geographic areas than the county level data often used in blizzard studies.

A study analyzing January and July cyclones and anti-cyclones in North America from 1950-1977 showed a decrease in frequency in both over this 28-year time frame, though these systems were still more frequent and stronger in January than in July (Zishka and Smith 1980). McCabe et al. (2001) examined the trends in both frequency and intensity of winter cyclones in the Northern Hemisphere for the years 1959-1997 and related them to temperature patterns. They found that frequency decreased with higher temperatures in the midlatitudes, whereas the higher latitudes saw frequency increase as temperatures increased. While both intensity and temperatures increased, the relationship between these two variables was not significant (McCabe et al. 2001).

Extreme events can be better understood through studies of exposure. Hurricanes, floods, and tornadoes are the most common focus of hazard research while winter

weather tends to be overlooked. Studies done on blizzard exposure and frequency is often done at the county level, which, as mentioned previously, can mask the banding trends common during snow events. However, differences across a county may be found using a different method that can provide smaller geographic detail, and this may increase understanding of the hazard and how it impacts an area.

The Great Plains boundary outlined by the Center for Great Plains Studies at the University of Nebraska-Lincoln and by Archer and Lonsdale (2003) was used as the study area boundary for this paper (Figure 2.1 inset). This area was chosen because of the higher frequency of blizzards here compared to the rest of the country. Calculating the frequency of hazard events is one way in which exposure can be determined. If the event happens more often, it is more likely to occur again in the future. Risk, therefore, increases since it is related to the probability of occurrence (Short, Jr. 1984).

This study examines the quantitative exposure of blizzards in the Northern Great Plains (Figure 2.1) using storm data for seasons of 1950/1951-2010/2011 and the months of October-April at a sub-county level to address the following questions: Which area(s) of the region experience the most blizzards? What month(s) are the most active? Is there a significant trend in frequency? Are blizzards more likely to occur during the winter months (December-February), during the late fall (October and November), or early spring (March and April)?

2. Methods and Data

The NOAA Daily Weather Map series, available online through the NOAA documents library and through the Weather Prediction Center (WPC) website, provided the data for this study. This source provides the daily morning weather maps for the

United States dating back to 1871, although the time of the map changed twice during the last sixty years. In 1958, the time changed from 0630 UTC to 0600 UTC. April 1968 saw the map time change from 0600 UTC to 1200 UTC, where it has remained. However, it is not believed this had any significant impact on the final results because these types of storms typically last for longer periods of time. A benefit of using digitized online copies is the ability to zoom in to ensure the station model could be read more easily and to verify the data is read correctly.

In the Northern Great Plains, blizzard season is considered to be November through March (Coleman et al. 2015) and snow season is between October and April (Kunkel et al. 2013). The snow season is the period of interest in this study for the years 1950/1951 through 2010/2011. For this study period, first-order weather stations in the study area were chosen and reported if they were under blizzard conditions. In order for a station to be selected for that day, the station model had to meet all of the NWS blizzard definition criteria:

1) Visibility of 1/4 mile or less
2) Wind speeds of at least 30 knots
3) Snow falling (indicated by **, ***, or **** symbol on the weather station model)

If these criteria are met, the station and date were recorded in a spreadsheet as a blizzard day for that station as were the temperature, wind speed, wind direction, visibility, and pressure. Stations that did not report information on more than 10% of the days in the sixty-one year period were not used for analysis. This mostly affected stations which were removed from the weather maps during the study period. Those stations, though,

were usually replaced with another station in the same area. Because the definition of "severe snowstorm" is subjective and can vary by location while the NWS blizzard definition is standard nationwide, the use of the official blizzard definition was ideal for this analysis.

However, this method may then miss storms that might have had a major impact on the region but did not reach blizzard status at the time of reporting. Using a once daily weather map thus has the potential for an underestimation of the true counts at each station as a storm may occur between one morning report and the next. Another potential source for undercounting is the fact that stations did not always report all necessary pieces of information to determine if blizzard conditions existed. Visibility was the most commonly missed variable on the station models, either because it wasn't reported or it could not be read. The earlier reports experienced the issue of illegibility more often because they were handwritten instead of automated, though this caused minimal problems. Spatial sampling may also be an issue because of the distance between first-order stations. Throughout the entire study area, only twenty-two stations are used with some states only having one station (such as Des Moines, Iowa). Blizzards occurring between these stations may then go unrecorded.

The number of days each station experienced blizzard conditions was tallied. The monthly data were also aggregated for just the early season (October-November), winter season (December-February), late season (March-April), and entire snow season (October-April). Early season and late season totals were combined to obtain a total count of non-seasonal storms. All categories were then mapped using the inverse distance weighted (IDW) interpolation method provided in ArcGIS 10 Geostatistical

Analysis toolbox (ESRI ArcGIS 10.3). IDW works under the assumption that points in close proximity have more of an effect on each other than those farther away, and the influence of neighboring points on each other decreases as the distance between them increases (Curtarelli et al. 2015; ESRI 2016). While this is not necessarily the case with weather events where localized banding may occur between data points, this interpolation method was used because it is the same method used in Heise (2013).

To eliminate the boundary effects of the interpolation as much as possible, data for stations in Kansas, Missouri, Illinois, Wisconsin, southern Canada and the entirety of Wyoming, Montana, and Colorado were included (Figure 2.1) and the resulting interpolation surface clipped to the states of interest. The areas determined to have the highest exposure in each classification are those which experienced the highest number days under blizzard conditions. To determine if a temporal trend exists in the frequency of blizzards, the total number of days for each year and group break down (seasonal, non-seasonal, early season, late season) in the dataset were tabulated and the data plotted. A regression trendline was fit to each graph to see if a significant pattern (at the 95% level) could be discerned over the sixty-one year period.

3. Results

a. Total Exposure

When considering the entire study period, South Dakota, especially the area around Rapid City, was shown to be the most exposed to a blizzard event (Figure 2.2a). The area of higher exposure extends north into eastern North Dakota and southwest towards Cheyenne, Wyoming. Table 2.1 lists the monthly and total blizzard counts for each station within the study area. Any station with a total over ten is in bold. Any

station with a total over twenty is in both bold and italics. Rapid City experienced twenty-two blizzard days during these sixty-one seasons, making it the most active city in the area. Pierre, South Dakota and Fargo, North Dakota are tied for second most active with fifteen days each. Only two other cities counted more than ten in this time period: Cheyenne, Wyoming (twelve) and Huron, South Dakota (eleven). Six of the twenty-two stations reported zero days under blizzard conditions in this study: Denver, Colorado; Miles City, Montana; Minneapolis, Minnesota; International Falls, Minnesota; and Des Moines, Iowa. An analysis of the temporal trend yields a slight decrease in frequency over time (Figure 2.2b), and this decrease is significant (Table 2.2, p-value = 0.001) even if the peak season of 1952/1953 is removed (p-value = 0.004).

The monthly breakdown of blizzard activity and exposure is shown in Appendix 2.A. For much of the region, March was the most active month with some stations reporting up to seven days throughout the study period. Most months, however, experienced no more than four blizzard days in the sixty-one years. No blizzards were recorded in the study area during the month of October, corroborating the argument by Coleman et al. (2015) that the blizzard season starts in November. South Dakota was again highlighted as an area of higher exposure each month, with the western portion of the state most active. Eastern North Dakota was also an area of higher activity, except for February and April. In February, the area around Duluth, Minnesota was the area of second highest activity. Most blizzard events in April were concentrated in South Dakota.

b. Seasonal versus Non-Seasonal Exposure

The monthly data was aggregated into seasonal (December-February), late season (March-April), and non-seasonal (October-November and March-April) and these are shown in Figures 2.3-2.5. Early season data (October-November) is shown in Appendix 2.B, but little activity occurred during these months compared to the late-season events. Western South Dakota is among the areas with the highest frequencies in all these monthly groupings. An analysis of the seasonal versus non-seasonal exposure shows that blizzards were more likely to occur during the late season months than during the winter months.

As discussed in the previous section, March is the most active month for blizzards. The maps for the seasonal grouping and late season grouping (Figure 2.3a and Figure 2.4a, respectively) exhibit very similar patterns with the main area around Rapid City, South Dakota extending southwest toward Cheyenne, Wyoming and a secondary area appearing around Fargo, North Dakota. The trend of the total number of days throughout the snow season showed a decrease in frequency during the winter months (Figure 2.3b). This trend was significant (p-value = 0.002) and remained significant when the 1952/1953 peak activity season was removed (p-value = 0.011) as shown in Table 2.2. The late season trend also showed a decrease in frequency (Figure 2.4b), but this trend was not significant (p-value = 0.157) and was further from significance with the removal of the 1965/1966 season (p-value = 0.286, Table 2.2).

Because most of the off-season blizzard days occurred during the month of March, the non-seasonal pattern (Figure 2.5a) closely resembles that seen with the late season counts (Figure 2.4a). Non-seasonal blizzard days exhibited a non-significant

decreasing trend (p-value = 0.067) in frequency as well (Figure 2.5b, Table 2.2). The 1965/1966 season was the most active for the non-season events, and the removal of this season resulted in the trend becoming more insignificant (p-value = 0.122).

Decadal trends were also plotted and are shown in Appendix 2.C in addition to a table of the total counts per decade. Analysis of the table shows an overall decreasing trend through the study period, with more than thirty blizzard days recorded for the 1950s and just three in the 2000s (one day for three different stations). Again, western South Dakota and eastern North Dakota are regions of higher blizzard exposure throughout each decade.

4. Discussion

In South Dakota, winter storms typically occur between late fall and mid-spring causing damage to property, people, and livestock. With most of the state being prairie (which provides little protection from the winds and blowing or drifting snow according to South Dakota Department of Public Safety[SDDPS]), no part of the state is safe from experiencing blizzard conditions. The Black Hills, because of their topography, do provide some resistance thus usually making these storms less severe. This topography, however, can cause the snow to drift more heavily than in other parts of the state. Some even refer to South Dakota as the "blizzard state" (SDDPS 2016). North and South Dakota are also in the general path of an Alberta Clipper, whose high winds can combine with falling or fallen snow to create the requisite low visibility conditions of a blizzard. The counts for the portions of Montana, Wyoming, and Colorado of interest are generally lower than the rest of the study area, and this could be a result of their position on the leeward side of the Rocky Mountains which means the systems have lost their moisture

after crossing the mountain range and are farther away from a secondary moisture source such as the Gulf of Mexico. This is not always the case, however, as can be seen with the higher frequencies around the city of Cheyenne as wind speeds can also increase as they descend the mountainside causing blowing snow and reduced visibilities.

Archives of *Monthly Weather Review* provided the information to help explain the patterns in blizzard days for some of the more active seasons. The 1952/1953 season was the most active season for blizzards in the study period with twelve blizzard days recorded. Ten of those days were during the winter months, mostly during February 1952 (nine of the ten days). The main storm that season occurred in South Dakota, Wyoming, Nebraska, and Minnesota on 19-21 February. This storm was what Smith (1953) called a "true 'Colorado Low'" (pg. 46) that moved through the Northern Plains into the Great Lakes bringing high winds and heavy snowfall to parts of the area. A review of the synoptic hemispheric conditions showed a major trough over the central United States during the month that corresponds with the higher amounts of precipitation found in the Northern Plains. The jet stream during February 1952 was also faster than usual combined with strong Foehn winds that brought warmer than normal temperatures to the Northern Plains (Smith 1953).

All blizzard days during the 1965/1966 season occurred during a storm from 4-5 March that moved slowly out of the Rockies into Nebraska and the Dakotas. Wind gusts during this blizzard reached 70 mph in parts of the Northern Plains, and nearly two feet of snow fell in Bismarck. A strong temperature gradient formed as cold air moved in from the west which helped to deepen the low pressure center of the storm while the blocking high in the east that dominated the monthly circulation remained in place,

preventing the system from quickly moving out of the Northern Plains region (Stark 1966).

During the final week of March 1975 (24-30 March), the southwestern United States saw a trough develop while a ridge formed over the eastern United States and Western Canada as the Westerlies shifted south. This circulation pattern steered below normal temperatures and two blizzards to North and South Dakota, leaving March 1975 as the snowiest month to date for parts of North Dakota (Taubensee 1975). Once again, March was responsible for the majority of the blizzard days recorded during this season with five of the seven days, all during the final week of the month.

All of the recorded blizzard days for the 1977/1978 season occurred during the blizzard of 8-9 November 1977 in portions of the Northern Plains. The central portion of the United States experienced a moderate trough with a weak ridge in western Canada during the month contributing to warmer and wetter conditions across parts of the Plains, once again leaving North Dakota with city snowfall records. However, during the week of 7-13 November, the Plains states saw a return of northerly winds which dropped temperatures below normal and created blizzard conditions across the region. Leading up to this storm, a ridge was building over the western United States while a trough moved north out of Louisiana, contributing to the northerly wind direction in the study area (Dickson 1977).

Another possible explanation for the trends in blizzard days may come from the three major teleconnections affecting the United States. The main one is the El Nino-Southern Oscillation (ENSO), and this is also one of the most studied teleconnections worldwide. Both the positive phase (El Nino) and negative phase (La Nina) are strongest

during Northern Hemisphere winter. For the Central United States, El Nino winters are typically warmer and wetter while La Nina winters are usually cooler and drier (NCSCO n.d., PMEL 2016). Using data from 1875-1980, Kurtzman and Scanlon (2007) found four main areas in the United States most impacted by ENSO. One of these regions they termed the High Plains, which is the North Central United States. Within this area, Nebraska and South Dakota are highlighted as states with a stronger ENSO response. This is partially explained by a more equatorward position of the Polar Jet during an El Nino winter, allowing for more cyclones to move through the area (Kurtzman and Scanlon 2007).

The decreasing number of blizzards over the decades could partially be explained by the strong El Nino events of the 1980s and 1990s. The 1997-1998 event, classified as the strongest on record, made that winter the warmest on record for portions of the Northern Plains. The National Climatic Data Center (NCDC) described the 1997-1998 El Nino as typical, which means that the jet stream kept the cyclones either farther north or farther south and out of the Northern Plains (Ross et al. 1998; Changnon 1999), in contrast to the results from Kurtzman and Scanlon (2007). With fewer cyclones moving through the area, it becomes more difficult for blizzard conditions to materialize. Two strong La Nina events also occurred during the latter part of the study period. However, the 1998-2000 La Nina created winter weather patterns for the Northern Plains that were more similar to an El Nino event (Shabbar and Yu 2009).

Another teleconnection that may explain the trends found is the North Atlantic Oscillation (NAO). During the positive phase of the NAO, temperatures and precipitation are usually above average because of a strengthening of the Midlatitude

Westerlies that allows cooler Arctic air to move offshore. The reverse occurs during a negative NAO with a weakening of the Westerlies which allows the cold air to collect in Canada leading to colder and drier winters (NCSCO n.d.; Sheridan 2003; CPC 2012). While the NAO has the strongest impact on the East Coast, some have argued that its affects can reach into the interior of the United States (Sheridan 2003).

The final teleconnection is the Pacific Decadal Oscillation (PDO), and the phases of this cycle typically persist for twenty to thirty years. The negative phase of the PDO dominated through the 1950s into the late 1970s. From the late 1970s through the end of the 20th Century, the positive phase was more prevalent. The PDO affects United States weather similarly to ENSO. If both PDO and ENSO are in the same phase (either positive or negative), the impacts of the ENSO event may become amplified. If, however, they are in opposite phases, the effects of the PDO may work to offset the effects of ENSO (NCSCO n.d.; Kurtzman and Scanlon 2007). Kurtzman and Scanlon (2007) found no significant impact on winter weather in the High Plains from the PDO alone, but the combination of the negative phases of both PDO and ENSO did have a significant impact (cooler and drier) in the region.

A comparison between the number of blizzard days in each season and the teleconnection phases for that season are shown in Appendix 2.D. Comparisons were done for the total number of days, seasonal (December-February) and non-seasonal (October-November and March-April) to see if a correlation may exist for any of these classifications that may help to explain the decreasing trend in the frequencies. There does not appear to be a consistent trend in any of these data to suggest the phases of

ENSO, PDO, and NAO may be able to be used in trying to predict how active the blizzard season may become.

The decreasing trends, though not all are significant, correspond well with the McCabe et al. (2001) study which suggested that a warming global climate may be linked to a lower frequency of midlatitude cyclones in the Northern Hemispheric midlatitudes. With fewer midlatitude cyclones developing during the snow season, some of the ingredients required for blizzard conditions to materialize may be removed. Removing the more active seasons in each category, the decreasing trend remained for each (not shown). However, the slopes of their respective trend lines all moved closer to zero (Table 2.2), and the R^2 values dropped, strengthening the suggestion that there has been no significant trend in the frequency of blizzards in the Northern Plains using this method. The twelve to fourteen-year cycle found by Coleman et al. (2015) for the contiguous United States is not found here, though the focus of this article is one region of the country instead of the country as a whole.

5. Conclusions

Blizzards are one of the main winter hazards that impact the Northern Plains, and this study focused on a different method of analyzing exposure patterns. Data for the months of October through April for the snow seasons of 1950/1951 through 2010/2011 showed that South Dakota is the state with the most blizzard activity, which was expected based on previous blizzard climatologies. Within the state, the western third exhibited the highest frequency. Secondary regions of peak activity were located in eastern North Dakota and central South Dakota. The analysis of monthly patterns showed that March

experienced the most blizzards followed by January and then February, and non-seasonal blizzards in total were more common than winter blizzards.

The area of highest frequency shifts from month to month and in each decade. However, Western South Dakota, eastern North Dakota are peaks of exposure in each month and each decade. The areas of high exposure are those in which midlatitude cyclones and Alberta Clippers are common during the cold season, bringing in conditions that are prime for the onset of blizzards. These events were rare during the first decade of the 21st Century, and more research will be needed to more fully understand the reasons behind this pattern.

While it was expected to see an overall increase in the number of blizzards based on previous blizzard studies, there was a significant decrease found in the overall frequency. The number of blizzards during the winter months also showed a significant decrease over the sixty-one year period. Neither the early season nor late-season trends were significant, though both also showed a decrease in frequency.

A cursory look at the connection between the number of blizzard days and ENSO, PDO, and NAO found no apparent connection. However, correlation and regression analyses between the number of blizzard days and the index values for these teleconnections needs to be done to see if there is indeed no connection to blizzard trends or if a significant relationship may exist. If these statistical analyses do suggest a significant relationship, forecasters and emergency managers may be able to use the teleconnection indices to improve seasonal forecasts on blizzards and winter storms.

While finding information to potentially explain the trends and patterns, it was discovered that the method presented here is conservative in estimating the number of

blizzards in the Northern Plains. For example, Kocin et al. (1998) discussed four blizzards recorded in the region for the month of January 1997, of which the methods used in this article found only one. It should also be noted that the interpolation method provides an estimate of the values between the data points, so the exact number of events that occurred in those areas is not known. It is possible that some areas between weather stations have higher frequencies than are shown here due to the potential banding nature of snow events and Alberta Clippers. It can be seen in Figures 2.2 through 2.5 that county level analyses may be hiding smaller and more localized trends in the exposure data. Some locations in the county may have higher exposure than others, which the method used in this article highlighted. Despite these limitations, the overall exposure patterns presented here appear to coincide with results seen in previous studies on blizzard climatology conducted at the county level: the Northern Plains were an area of frequent blizzard activity, and the Dakotas were the most active within the region.

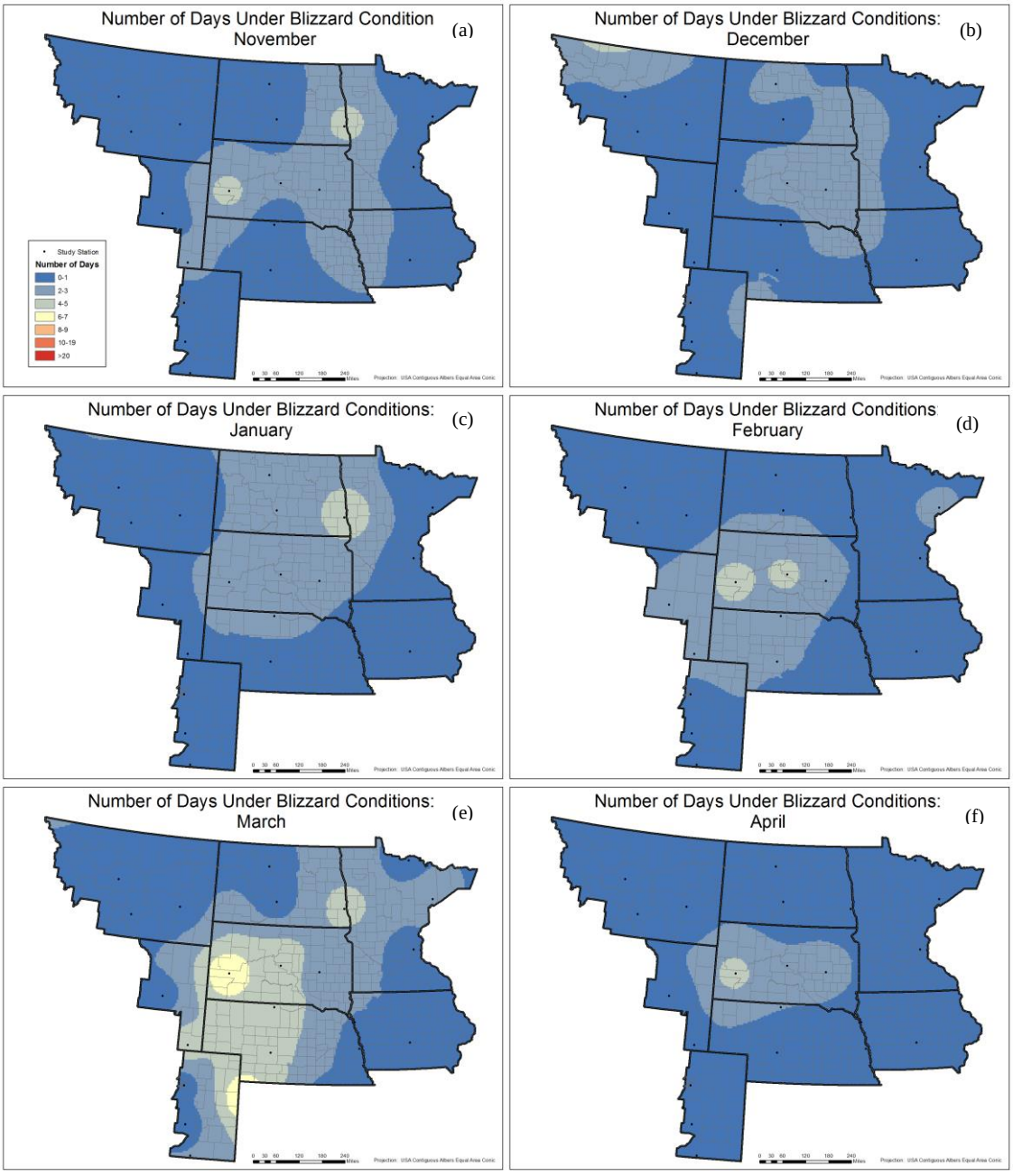
A possible solution to the spatial sampling limitations is the creation of statewide networks, such as the Oklahoma Mesonet, in which there is at least one station in each county. While some states are expanding and creating such networks, they do not yet have enough data to provide a climatological record. Nebraska has a Mesonet system, but their system does not cover all ninety-three counties in the state. Without statewide networks, interpolation using first-order stations provides an alternate to county-level analyses and may help to highlight the need for such statewide weather networks in places like the Northern Plains. Exposure, however, is just one part of the equation. Research into how the residents of the Northern Plains perceive the threat of blizzards

and how they prepare for winter and winter storms is forthcoming as is an analysis of their overall social vulnerability to a potential blizzard disaster.

6. Appendices

2.A: *Monthly Exposure*

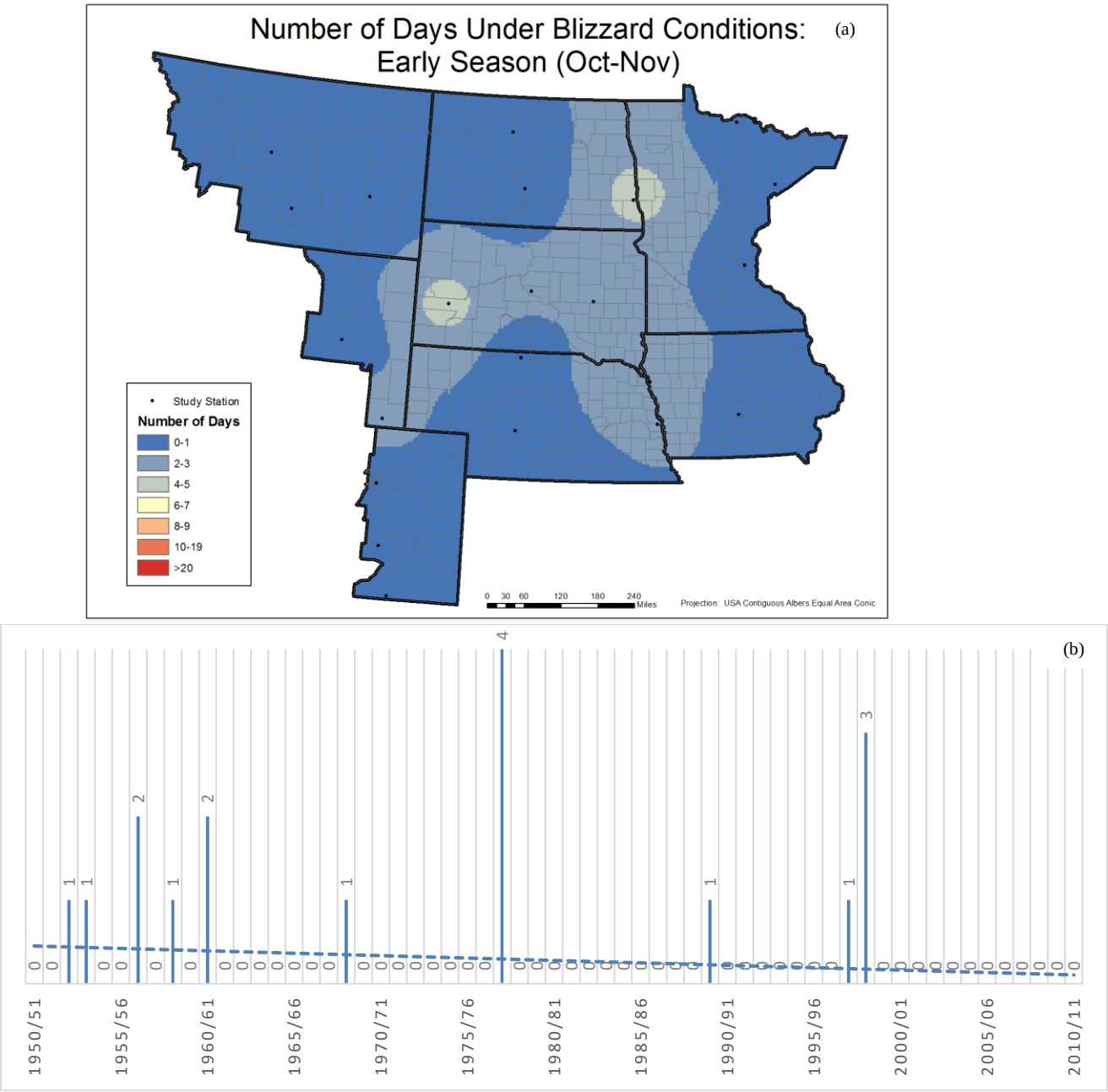
Analysis of both the numbers and mapped patterns shows that March is the most active month for much of the region (panel e) and October the least (not shown) with no blizzards recorded in the study area. Areas of highest exposure shift from month to month. November (panel a) shows three regions of higher frequency: western South Dakota, eastern North Dakota, and northeast Nebraska/northwest Iowa. Northwest Montana and eastern South Dakota are the peak regions during the month of December (panel b), while eastern North Dakota is the area of most concern during January (panel c). February and March (panels d and e, respectively) have the most activity in western and central South Dakota south into the panhandle of Nebraska and southwest Wyoming. South Dakota is also the area of highest frequency in April, especially in the western part of the state around Rapid City (panel f). Though the exact hot spots shift through the months, eastern South Dakota is again highlighted as an area of high exposure for blizzards. All panels use the color scheme shown in panel a, which is the same scheme used in Figure 2.2-2.5.



2.B: *Early Season Exposure*

In regards to the early season events, three areas are highlighted for the highest exposure: western South Dakota, eastern North Dakota, and northeastern Nebraska/northwestern Iowa (panel a). Once again, there was no significant decrease (p-value = 0.298) in the number of early season event (panel b). While removing the most

active season (1977/1978) caused this trend to get closer to a significant p-value (0.227), the trend remained insignificant at the 95% level.



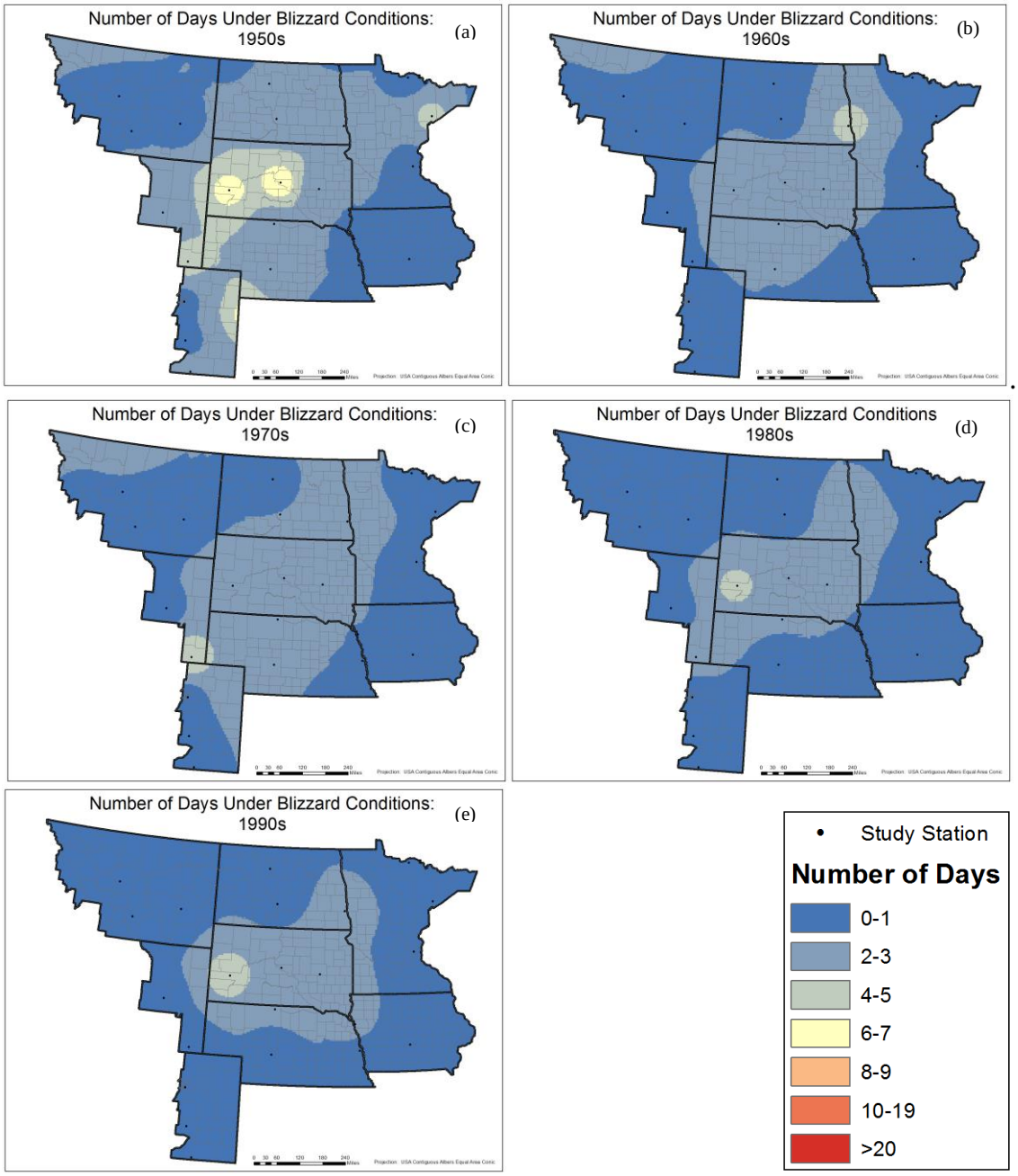
2.C: *Decadal Patterns and Trends*

As has been the case throughout, South Dakota shows as a consistent hot spot throughout the decades. The 2000s are not shown because the entire study area falls into

the 0-1 blizzard day category. The table lists the decadal totals for the entire study area, determined by totaling the counts for each station for all the years in that decade. The numbers show a decrease in the frequency each decade from a high of thirty-six total days in the 1950s to just three blizzard days in the 2000s, one each in Rapid City, South Dakota; Sioux City, Iowa; and Minot, North Dakota (Table 2.3).

In the 1950s, western South Dakota into northeast Colorado showed the highest blizzard activity with a secondary peak around Duluth, Minnesota (panel a). The high-frequency area expanded to all of South Dakota and extended into eastern North Dakota and north central Nebraska in the 1960s (panel b). While the highest exposure during the 1970s was in southeast Wyoming, western South Dakota and eastern North Dakota were still showing higher levels of activity compared to the rest of the Northern Plains (panel c). During the 1980s and 1990s, the peak in activity had again shifted back into western South Dakota and eastern North Dakota with secondary peaks throughout the rest of South Dakota (panels d and e, respectively).

Decade	Number of Days under Blizzard Conditions
1950/1951 - 1959/1960	36
1960/1961 – 1969/1970	22
1970/1971 – 1979/1980	23
1980/1981 – 1989/1990	16
1990/1991 – 1999/2000	15
2000/2001 – 2010/2011	3
Total	115



2.D: Total number of blizzards days in the study area for each snow season (total, seasonal, non-seasonal, early season, and late season) with the phase of ENSO, PDO, and NAO for that year. Phase was determined by averaging the monthly index scores for each of the three teleconnections from October through April. Values between -0.5 and +0.5 were considered neutral.

Snow Season	Total Number of Blizzard Days	Winter Blizzard Days	Non-season Blizzard Days	ENSO phase	PDO phase	NAO phase
1950/1951	6	4	2	Negative	Negative	Negative
1951/1952	5	5	0	Positive	Negative	Negative
1952/1953	12	10	2	Neutral	Negative	Negative
1953/1954	3	1	2	Positive	Negative	Negative
1954/1955	1	1	0	Negative	Negative	Negative
1955/1956	2	2	0	Negative	Negative	Negative
1956/1957	4	0	4	Neutral	Negative	Negative
1957/1958	2	2	0	Neutral	Positive	Neutral
1958/1959	1	0	1	Neutral	Positive	Neutral
1959/1960	0	0	0	Neutral	Positive	Neutral
1960/1961	2	0	2	Neutral	Neutral	Negative
1961/1962	1	0	1	Neutral	Negative	Negative
1962/1963	3	3	0	Neutral	Neutral	Negative
1963/1964	2	1	1	Positive	Neutral	Negative
1964/1965	1	1	0	Negative	Negative	Negative
1965/1966	8	0	8	Positive	Neutral	Negative
1966/1967	0	0	0	Neutral	Neutral	Neutral
1967/1968	1	0	1	Negative	Neutral	Neutral
1968/1969	4	3	1	Positive	Negative	Negative
1969/1970	0	0	0	Positive	Positive	Negative
1970/1971	1	0	1	Negative	Negative	Negative
1971/1972	0	0	0	Negative	Negative	Neutral
1972/1973	3	0	3	Positive	Neutral	Neutral
1973/1974	1	1	0	Negative	Negative	Neutral
1974/1975	7	2	5	Negative	Negative	Neutral
1975/1976	2	0	2	Negative	Negative	Neutral
1976/1977	4	0	4	Positive	Positive	Negative
1977/1978	4	0	4	Positive	Neutral	Negative
1978/1979	0	0	0	Neutral	Neutral	Neutral
1979/1980	1	1	0	Positive	Positive	Neutral
1980/1981	0	0	0	Neutral	Positive	Neutral
1981/1982	2	1	1	Neutral	Neutral	Neutral
1982/1983	2	2	0	Positive	Positive	Neutral
1983/1984	2	1	1	Negative	Positive	Neutral
1984/1985	1	0	1	Negative	Neutral	Neutral
1985/1986	3	0	3	Neutral	Positive	Neutral
1986/1987	0	0	0	Positive	Positive	Positive
1987/1988	3	2	1	Positive	Positive	Neutral
1988/1989	2	1	1	Negative	Negative	Positive
1989/1990	1	0	1	Neutral	Negative	Positive
1990/1991	0	0	0	Neutral	Negative	Neutral
1991/1992	0	0	0	Positive	Neutral	Positive
1992/1993	0	0	0	Neutral	Positive	Neutral
1993/1994	1	0	1	Neutral	Positive	Positive
1994/1995	1	1	0	Positive	Negative	Neutral
1995/1996	3	2	1	Negative	Positive	Negative
1996/1997	6	3	3	Neutral	Neutral	Neutral
1997/1998	1	0	1	Positive	Positive	Negative
1998/1999	3	0	3	Negative	Negative	Neutral
1999/2000	0	0	0	Negative	Negative	Positive
2000/2001	1	1	0	Negative	Negative	Neutral
2001/2002	0	0	0	Neutral	Negative	Neutral
2002/2003	0	0	0	Positive	Positive	Negative
2003/2004	0	0	0	Neutral	Neutral	Neutral
2004/2005	0	0	0	Neutral	Neutral	Neutral
2005/2006	0	0	0	Negative	Negative	Neutral
2006/2007	0	0	0	Positive	Negative	Neutral
2007/2008	0	0	0	Negative	Negative	Neutral
2008/2009	1	0	1	Negative	Negative	Neutral
2009/2010	1	1	0	Positive	Neutral	Negative
2010/2011	0	0	0	Negative	Negative	Neutral

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8. Tables

Table 2.1: Total number of days under blizzard conditions for each month, each category, and the overall total for each station in the study area. Stations with totals over ten are in bold. Stations with totals over twenty are in bold and italics.

Station	Jan	Feb	Mar	Apr	Oct	Nov	Dec	Total
Denver, CO	0	0	0	0	0	0	0	0
Pueblo, CO	0	1	0	0	0	0	0	1
Trinidad, CO	0	0	1	0	0	0	1	2
Miles City, MT	0	0	0	0	0	0	0	0
Billings, MT	0	0	0	1	0	0	0	1
Lewistown, MT	0	0	0	1	0	0	1	2
Valentine, NE	2	1	4	1	0	0	0	8
North Platte, NE	0	1	3	0	0	0	1	5
Omaha, NE	0	0	0	0	0	2	0	2
Huron, SD	**2**	**1**	**2**	**2**	**0**	**1**	**3**	**11**
Pierre, SD	**2**	**4**	**5**	**1**	**0**	**1**	**2**	**15**
Rapid City, SD	***2***	***4***	***7***	***4***	***0***	***4***	***1***	***22***
Bismarck, ND	1	1	0	0	0	0	0	2
Fargo, ND	**5**	**0**	**4**	**0**	**0**	**4**	**2**	**15**
Minot, ND	1	0	0	0	0	0	2	3
Minneapolis, MN	0	0	0	0	0	0	0	0
International Falls, MN	0	0	0	0	0	0	0	0
Duluth, MN	0	2	3	0	0	1	1	7
Des Moines, IA	0	0	0	0	0	0	0	0
Sioux City, IA	0	0	1	0	0	3	2	6
Casper, WY	0	1	0	0	0	0	0	1
Cheyenne, WY	**1**	**3**	**4**	**1**	**0**	**2**	**1**	**12**
Total	16	19	34	11	0	18	17	115

Table 2.2: Slope and significance of the temporal trend lines for each category. Significance was tested with and without the peak activity seasons. P-values significant at the 95% level are in bold and the season removed is given in parenthesis.

Storm Count Category	Slope	p-value	p-value without peak season of activity (season)
Total Days	-0.056	**0.001**	**0.004** (1952/1953)
Seasonal Days	-0.035	**0.002**	**0.011** (1952/1953)
Early Season Days	-0.006	0.298	0.227 (1977/1978)
Late-Season Days	-0.015	0.157	0.286 (1965/1966)
Non-Seasonal Days	-0.021	0.067	0.122 (1965-1966)

9. Figure Caption List

Figure 2.1: Location of the stations used for the exposure analysis. Stations located within the study area are designated by the stars. Stations outside of the study area used to lessen the edge effects during the interpolation process are designated by the circles. Inset shows the boundary of the Great Plains according to the Center for Great Plains Studies, obtained from http://www.unl.edu/plains/about/map.shtml.

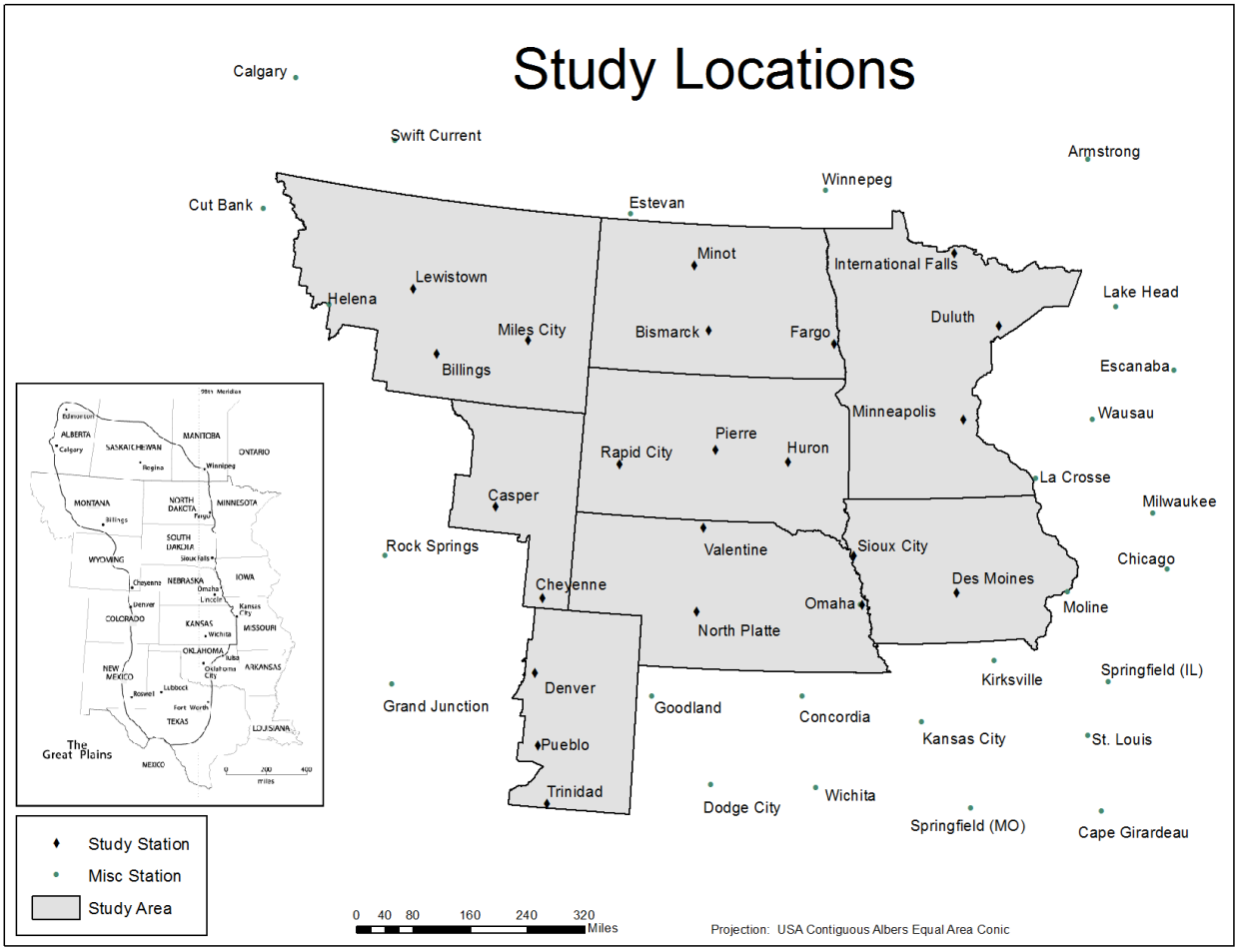
Figure 2.2: Total exposure map (a) and trend graph (b) for number of days under blizzard conditions. Darker blues indicate lower frequencies. Oranges and yellows indicate higher frequencies. Red indicates more than twenty days.

Figure 2.3: Seasonal exposure map (a) and trend graph (b) for number of days under blizzard conditions. Colors same as in Figure 2.2

Figure 2.4: Late season exposure map (a) and trend graph (b) for number of days under blizzard conditions. Colors same as in Figure 2.2

Figure 2.5: Non-seasonal exposure map (a) and trend graph (b) for number of days under blizzard conditions. Colors same as in Figure 2.2

10. Figures



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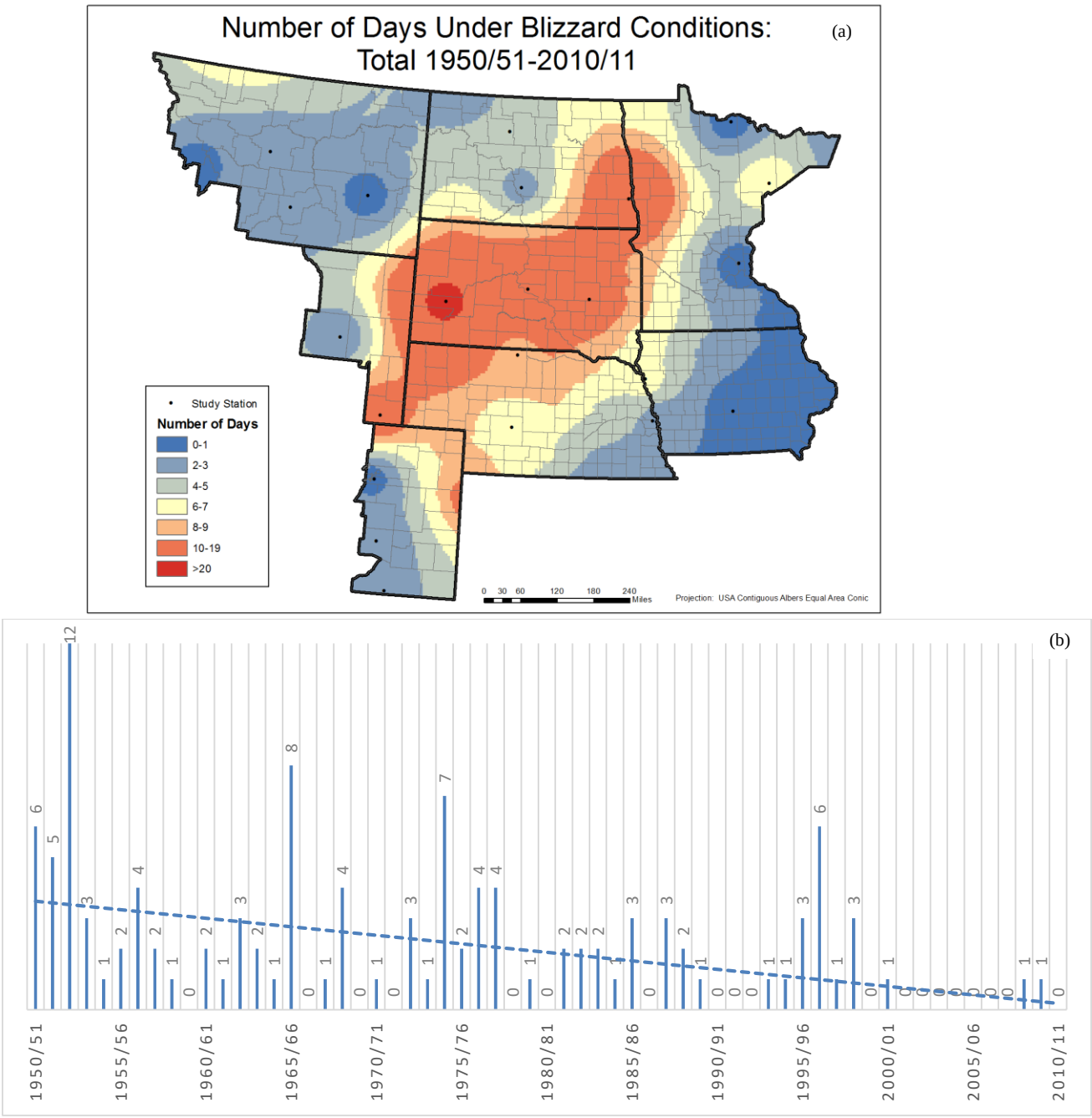

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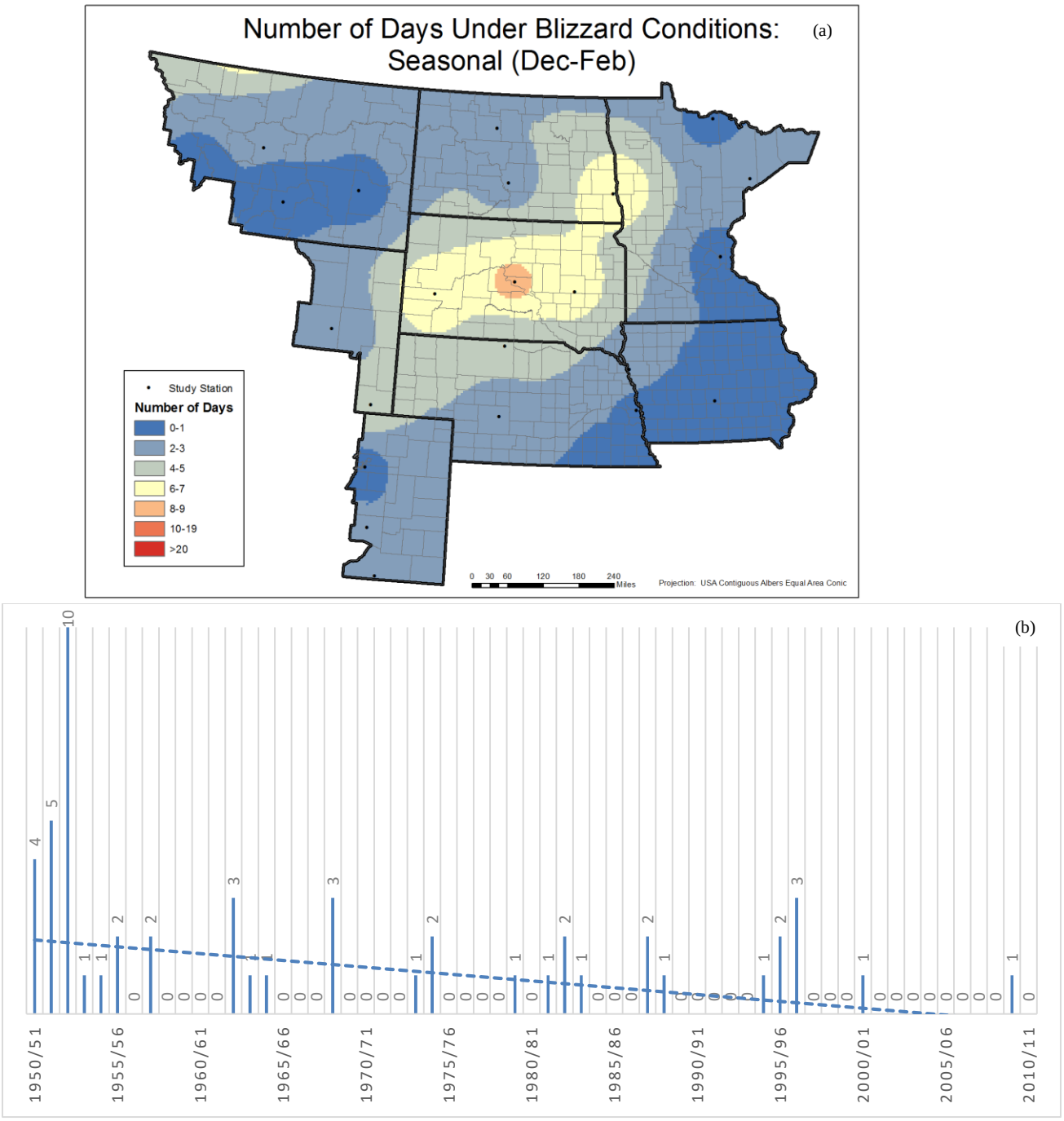


Figure 2.3: Seasonal exposure map (a) and trend graph (b) for number of days under blizzard conditions. Colors same as in Figure 2.2

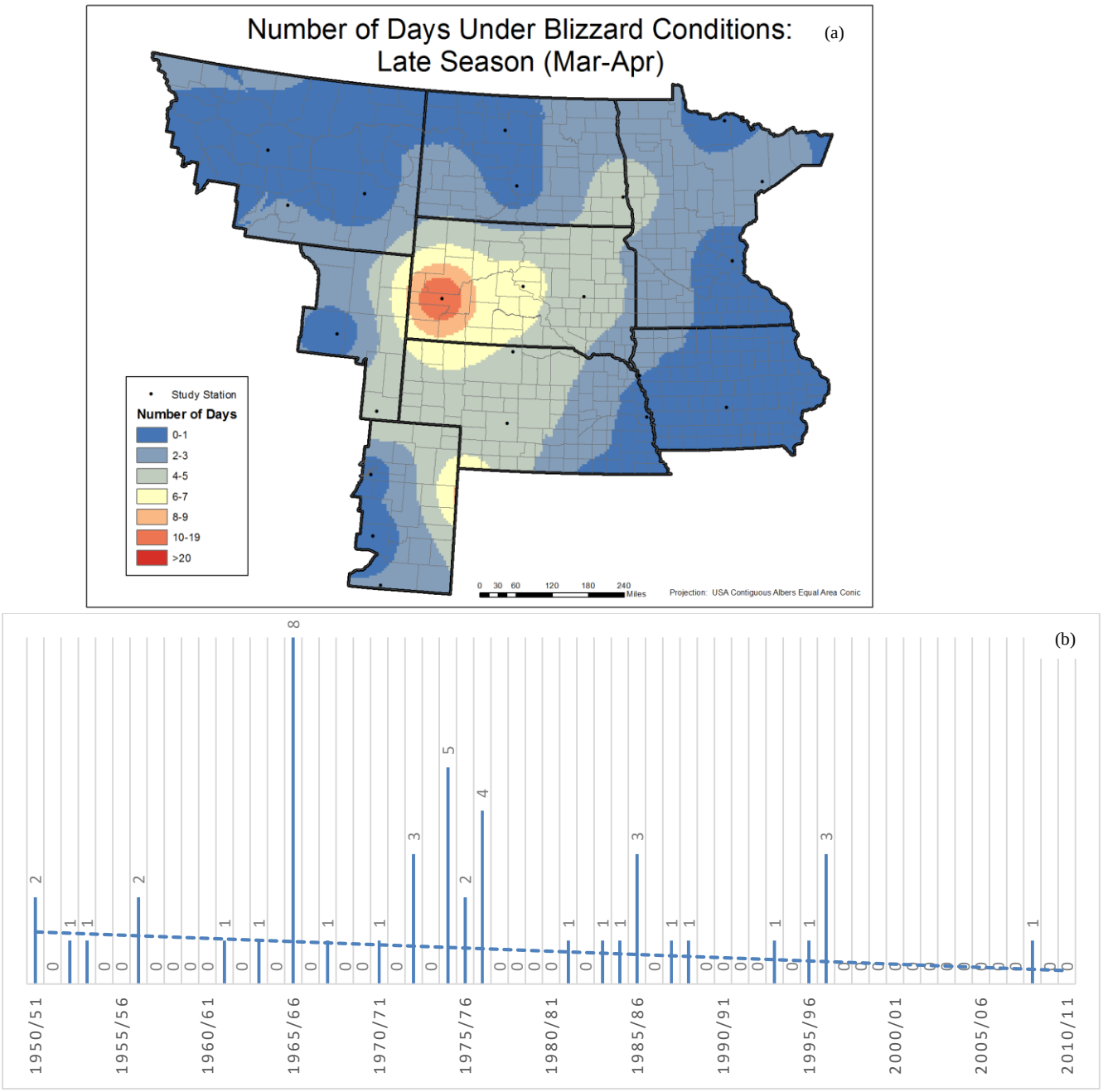


Figure 2.4: Late season exposure map (a) and trend graph (b) for number of days under blizzard conditions. Colors same as in Figure 2.2

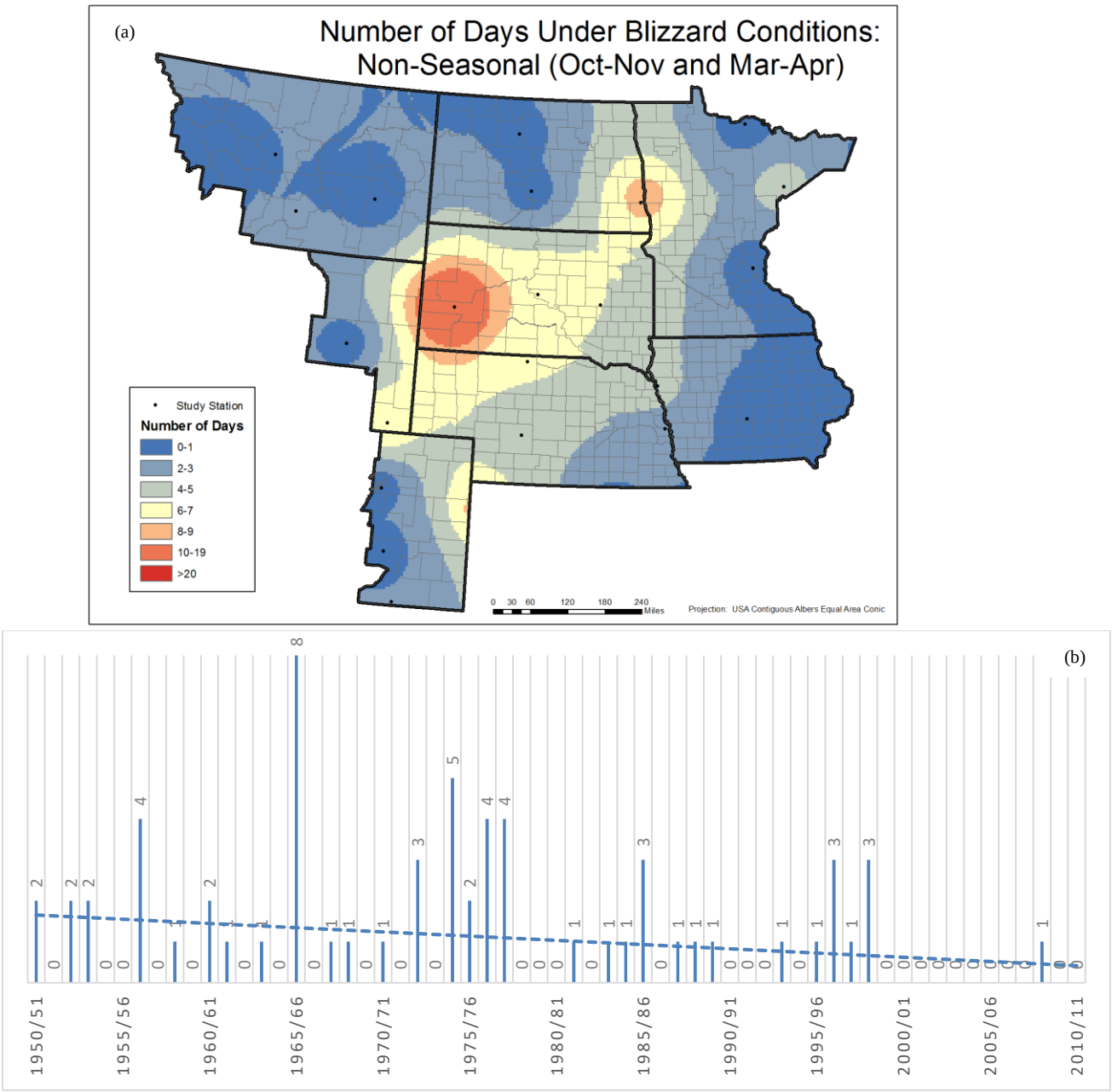


Figure 2.5: Non-seasonal exposure map (a) and trend graph (b) for number of days under blizzard conditions. Colors same as in Figure 2.2

CHAPTER III

BLIZZARD PERCEPTION AND PREPAREDNESS: A CASE STUDY OF THE DAKOTAS

Authorship and Journals

The title of this chapter, "Blizzard Perception and Preparedness: A Case Study of the Dakotas," is the planned title for this article, and I propose to be the sole author. Because the research for this article focuses on understanding the perceptions and levels of preparation to a meteorological hazard, a journal through the American Meteorological Society (AMS) or specifically dedicated to risk perception would be the types of journals chosen. Potential journals for publication of this article would be those such as the Journal of Applied Meteorology and Climatology (JAMC) or Weather, Climate, and Society (WCAS). Both of these journals are publications of AMS that publish articles relating to the interaction of society and the environment. The JAMC description includes climate risk and vulnerability among the topics covered in their articles, while the main focus of WCAS is the interaction of weather with society. Another potential journal would be Risk Analysis, which is a journal published by the Society for Risk Analysis that has published articles on risk perception. The final journal under

consideration is Natural Hazards, and this is a journal published by the International Society for the Prevention and Mitigation of Natural Hazards

Abstract

Blizzards are one of the main hazards for the Northern Great Plains, and the Dakotas experience more of these storms than anywhere else in the United States. Blizzard studies usually focus on the climatology, and perception surveys are usually concerned with events such as floods and hurricanes. The surveys that have been done on blizzards have not allowed the respondents to elaborate on their views or actions. For this article, online surveys were conducted with the residents of North and South Dakota to ascertain their perception of the problem as well as how they prepare for blizzards. A total of 151 surveys were returned. Six of the thirty-five questions were open-ended and are the focus of this article. The vast majority of respondents have experienced at least five blizzards with travel and service disruption a main concern across five of the six questions. Women were more likely than men to include disruption of service in their definitions and to mention this when describing experiences. Hazard professionals and those with more formal education mentioned the issue of travel disruption during blizzard warnings more frequently than their counterparts. Concerns with weather and road conditions was more common for rural residents than those in the city. Those with below average homeplace were more likely than those with above average homeplace to say their community leaders needed no improvement in how they responded to blizzards. Income was not significant in determining how respondents answered these six questions.

1. Introduction

Hazards are events that threaten communities and the things they value. They can be categorized in one of three ways: meteorological (i.e. temperature extremes, hurricanes, blizzards), geological (i.e. earthquakes, landslides), or hydrological (i.e. floods, ENSO). If the event occurs and the affected community is unable to cope with the impacts, it becomes a disaster (Gregg and Houghton 2006). The most persistent disaster losses tend to occur in rural areas such as the Great Plains. Most rural areas within the United States are seeing populations decrease, except portions the Northern Great Plains because of the energy industry (Cromartie 2016). Rural areas can be seen as more socially vulnerable because of a lack of human and financial resources, but the tendency for rural areas to be more self-reliant and have stronger social connections can, in turn, reduce their social vulnerability (Cutter, Ash, and Emrich 2016). The Northern Great Plains, which are generally considered to be more rural than urban, may be able to illustrate this because of the higher chance of ice and snow events during the winter.

Even in places where winter weather events are common, an extreme snowstorm can become a disaster (Smith 1992b). Because severe snowstorms and blizzards are relatively common in the Northern Plains, the residents may become complacent which may increase social vulnerability. However, the commonality of these storms might also increase resilience in that the residents take necessary precautions. Few surveys on perception and preparation have been done on blizzards with most of the focus going to climatological studies. Most perception and preparedness surveys on meteorological hazards is on storms such as floods or hurricanes. This article was designed to assess the

perception and preparedness levels for two states of the Northern Plains that showed highest exposure levels in previous research (Heise 2013).

Historically, hazards have been the purview of geography while sociology was more focused on disasters (Cutter 2001). Now, research is increasingly interdisciplinary. Initially, the idea was to understand the geographic extent of the hazard and determine the ideal adjustments to mitigate loss. Recently, the need for understanding the sociopolitical context has been added (Cutter 2001) because both the causes and consequences of a disaster stem from the social structure and social processes of the affected community (Kreps 1984). According to Montz, Cross, and Cutter (2003), the questions in the disaster field have grown to include the need for sociopolitical context and a focus on total risk, which includes understanding perception and preparedness.

As was argued by Weichelgartner (2001), preparedness, which is any action taken to minimize loss, is one of the key components to understanding social vulnerability; and risk perception is a key component when deciding how (or if) to prepare. In the early years, studies on risk perception showed that people in the communities know how to reduce their losses. However, it is experience with the hazard along with socioeconomic factors that determine if they take those actions (Rooney 1967; Kreps 1984; Cutter 2001; Gierlach, Belsher, and Beutler 2010). Rooney (1967) conducted surveys with residents of seven cities experiencing high snowfalls, including Rapid City, South Dakota, as part of his work on the urban snow hazard. In that study, it was argued that public communication and coordination between various agencies was necessary to mitigate against snow hazards. He also found that people are less likely to institute changes the longer they wait after the severe snow event. The residents of these seven cities found

heavy snows to be more of an annoyance than a major problem, and Rooney found they are more likely to be underprepared for a major event (Rooney 1967). In a study on blizzard preparations in Ohio in January 1978, it was shown that societies may become complacent when the events happen in rapid temporal succession (Neal, Perry Jr., and Hawkins 1982). This complacency may lead to less preparation, and inadequate preparation and complacency may increase social vulnerability.

Perception has also been tied to the concept of place attachment. Place attachment, or sense of place, is the connection a person has with their environment and has been applied to disaster studies in the past in regards to forced relocation (i.e. evacuations) and the impact on environmental perceptions. The idea of place attachment was first mentioned more than forty years ago, and many studies have found that people become attached to places even if they are shown to be a high risk area. Many factors can influence this attachment: diversity, number and type of services, social capital, education, and length of time in the area. Length of time, though, has been shown to be one of the strongest indicators of attachment (Vorkinn and Riese 2001; Scannell and Gifford 2010; Lewicka 2011; Cresswell 2013).

Scannell and Gifford (2010) argue that place attachment can serve many functions. One of these is for security and survival in which the resources of the place become important. If these resources help advance the person's goals, it also serves the purpose of support and self-regulation. The final function Scannell and Gifford discussed was continuity or stability. For many rural places such as the Northern Plains, land is kept in the family for generations and thus people may become strongly attached to the land, continuing to pass it down through the family. The authors also suggest that strong

place attachment may lead to behaviors that improve their community (Scannell and Gifford 2010). In a study of potential hydropower developments in Norway, Vorkinn and Riese (2001) found that stronger place attachment lead to more opposition to the development project and place attachment was a stronger control of this opposition than the sociodemographic variables.

Perception is just one of the factors influencing the way in which people react and behave when it comes to risks and disasters. Some argue that the main difference in behavior is time scale: disaster behavior is focused on the past while risk behavior is focused on the future. Actions taken are based on experiences that a person is trying to prevent from reoccurring (Stallings 1997). Different theories about behavior, such as chaos theory and resource mobilization, can be used to explain how and why people make the decisions they do. These two theories help to understand the processes through which people may come to view the issue, and their perception of the problem determines the resources they access (or try to access) to mitigate the impacts.

Resource mobilization is securing control over a needed resource. Which resources are significant is not universal, but the need for outside contributions and cooperation is significant. While some argue that the collective interests driving mobilization exist prior mobilization, others argue they are emergent with new behaviors and ideas developing in the moment (Jenkins 1983). However, it is possible both are correct. Available resources are constrained by things such as system conditions, competition, transportation, media attention, and those in control of the resource (McCarthy and Zald 1977).

Although resource mobilization usually refers to social movements, the same ideas can be applied to disasters. Disasters impact entire communities and can create a collective trauma (Kaniasty and Norris 1995) viewed as the collective interest through which the community comes together to mobilize resources. One such resource could be support from neighbors. Kaniasty and Norris (1995) use these ideas to examine mobilization and loss of social support after a natural disaster using Hurricane Hugo and flooding in Kentucky. Support is either received, perceived (it is there if needed), or socially embedded (number of existing relationships and type). Received support could be viewed as the mobilization of the resources. However, support and aid provided are unevenly distributed, with those most impacted receiving priority. They also found characteristics such as sex, age, and education determined who did or did not receive support. Educated white males were more likely to receive support than minorities and the poor (pattern of neglect). When it came to age, the elderly were more likely to receive support if their health was at risk (pattern of concern). Although, if this concern did not exist, they were more likely to fall victim to the pattern of neglect. If the perceived support does not materialize (resource not mobilized), the impacted communities are more likely to experience higher levels of stress (Kaniasty and Norris 1995).

Another theory that can be used to explain behavior is chaos theory: events do not follow a linear path and cannot be predicted using conventional cause-and-effect methods. Chaotic systems can reorganize and renew themselves, and they exhibit periods of stability broken up through sudden and irreversible events, such as a disaster (Murphy 1996). Using chaos theory for issue or crisis management, the goal is to discover trends

in the system to try to prevent reaching the tipping point. An example of a chaotic system is public opinion (Murphy 1996), such as risk perception.

While all potential outcomes cannot be accounted for, qualitative methods, such as surveys, can become important as a way to simulate the chaotic system, but one must always remember that the simulation will likely not predict the actual outcomes. Also, the disaster can expose problems that were not previously known or create new issues between the community and government (Piotrowski 2006).

In terms of risk perception, those populations that have less control over their situation tend to see a higher risk to their property and resources (Morrow 1999; Cutter, Boruff, and Shirley 2003; Buckle 2006; Cutter and Emrich 2006; Borden et al. 2007; Cutter et al. 2008; Yoon 2012). Females, hazard professionals (i.e. medical personnel, firefighters, police, and other governmental workers), those with more formal education, and those with a higher income are also expected to have increased risk perceptions and preparation levels (Short, Jr. 1984; Thomas et al. 2013). For females, the research suggests that the typical gender roles resign women to care for the home and the family while men are more likely to take a more hands-on approach to recovery and go out into the community to help. Hazard professionals, the more highly educated, and those with a higher income may have access to more resources and knowledge and are thus able to understand the risk more clearly and take increased mitigative actions (Short, Jr. 1984; Thomas et al. 2013).

Though blizzard perception studies are not common, Schwartz (2000) conducted a survey on perception while creating his blizzard climatology. This survey, though, consisted of only closed-ended questions in which the respondents were given a list of

choices when asked about their definition of a blizzard, leading to highly accurate responses on what constituted a blizzard. This was done after a pre-test of the survey found those answering the open-ended version were not as accurate as those answering the closed-ended questions, which he used to justify only using the latter version (Schwartz 2000). However, providing the respondents with choices might have produced biased results that may not have been found if the question was left open-ended.

To address the concerns with Schwartz's survey and to see if the existing trends of the literature apply to an underrepresented hazard, the questions to be asked in this study are: How do the residents of the Dakotas define a blizzard and describe their blizzard experiences? Where do they feel their community leaders need to improve, if at all? How do they prepare for blizzard watches versus blizzard warnings? What are the concerns of ranchers/farmers in the event of a blizzard? Are there differences between various social groups in these responses?

2. Methods and Data

Structured surveys consisting of both closed and open-ended questions are one of the most common mixed methods instruments. Web-based surveys are being used more frequently, in place of in-person or telephone surveys. Internet surveys can be cheaper and quicker to administer, access more geographically dispersed populations, and may produce higher response rates. However, sampling bias in Internet surveys could be more acute. The researcher does not have as much control over the respondents which may not result in a representative sample (McLafferty 2010; Bazeley and Jackson 2013).

Ensuring confidentiality and anonymity, data security, and informed consent also become a concern (Coomber 1997; McLafferty 2010; Madge 2010). There are survey

companies dedicated to helping academics conduct online surveys with multiple measures in place to help alleviate these concerns, such as encryption and not recording IP addresses. One such site is Survey Monkey (surveymonkey.com), which was the company used for this study.

Open and closed-ended survey questions were used to ascertain the perception and preparedness levels of the residents in North and South Dakota (Figure 3.1a). These states were chosen because of their high level of blizzard activity compared to the rest of the region (Figure 3.1b). Any resident eighteen or older was eligible. Potential respondents were selected, contacted, and provided the survey via Survey Monkey, initially through random sampling and then snowballing, in which initial contacts were encouraged to introduce new respondents by sharing the survey with others in their community. The initial sample size was 100 residents per state contacted via Survey Monkey's email database (created through previous respondents of Survey Monkey questionnaires).

The surveys were distributed in September 2016 and took approximately fifteen to twenty minutes to complete. No personal information such as email or IP addresses were collected or saved, minimizing the risk of the respondents' identities being discovered. The survey and methods were approved by the Oklahoma State University Institutional Review Board (IRB, approval AS-15-115). A total of 151 surveys were returned, ninety-five from North Dakota and fifty-six from South Dakota.

The survey was written using preparedness and perception studies from the literature (White 1974; Neal, Perry Jr., and Hawkins 1982; Mileti 1999; Smith 1992a; Bourque, Shoaf, and Nguyen 2002; Senkbeil et al. 2014) in addition to blizzard-specific

preparation information from the Red Cross and the National Oceanic and Atmospheric Administration (NOAA). The survey, which can be found in Appendix 3.A, consisted of thirty-five questions. Six of these questions were open-ended and are the focus of this article. Residence time and age were combined to create a variable known as homeplace (residence time divided by age). This variable ranges from zero to one, with values closer to one indicating the resident has lived in the area for much of their life (Ritchie, Gill, and Long 2015).

The responses to five of the open-ended questions were coded using open coding. Open-coding is the process through which the codes/themes emerge as the coding process advances instead of going in with a pre-conceived list of codes/themes to find (known as closed-coding). Because the blizzard definitions were compared to the official definition from NOAA and NWS, closed-coding was used to find information on wind, snow, visibility, temperature, loss of services/road conditions, and duration. Responses were analyzed using six binary demographic groups (male vs. female, hazard professionals vs. non-professionals, urban vs. rural, below average vs. above average homeplace, less than a Bachelor's degree vs. at least a Bachelor's degree, and less than $50,000 vs $50,000 or higher annual income). The resulting codes for the entire dataset as well as the demographic subsets were tallied to provide code frequency tables and representative quotes used to illustrate the main themes found in the analysis.

To try to ensure reliability and validity of the results, the progress was discussed with colleagues familiar with the coding techniques. Each person was provided a copy of the responses and the codebook to code the materials, and the group then met to discuss the codes. When a discrepancy was found, each person discussed their rationale and a

consensus reached on which code would be most appropriate. For the community leader perception questions, the percentage of respondents for each answer choice were calculated and graphed using the demographic binaries to provide context for the open-ended community leader question.

A two-tailed Fisher's Exact Test was used to see if significant differences existed between the various groups on each of the resulting codes. Binary tables were created with the demographic group. Each response that included the code is counted as a "yes" while responses that did not include the code or did not answer that question counted as "no." For example, each respondent that identified as male who included a description of "wind" in their blizzard definition was marked as "yes." If the male respondent either did not include a "wind" component or did not answer the definition question, his response was marked as a "no." Only those codes in which both demographic components had a count of at least five were analyzed for significance.

3. Results

Demographic summaries of the respondents can be found in Table 3.1. In terms of experience, most people have been through at least five blizzards in their lifetime. The average age of the respondents was 54.21 years (compared to 37 years according to U.S. Census), and the respondents had lived in the area for an average of 25.33 years resulting in an average homeplace of 0.47. The majority (~97%) of those filling out the survey were white (nearly 90% white on the U.S. Census) with one Asian-American and three Native Americans. Most of the respondents have earned at least a Bachelor's degree (55% compared to approximately 28% in the U.S. Census). Median income for North

and South Dakota, according to the U.S. Census, was around $57,000, and approximately two-thirds of the survey respondents indicated an annual income at least $50,000.

Around 60% of the respondents were female (50% from the U.S. Census), and nearly three-quarters identified as living in the city/town. The U.S. Census Bureau identifies urban regions as those with a population of at least 2500, and the U.S. Census showed approximately 60% of the Dakotas' population as urban. Many towns in the Plains states may have populations below 2500, and they would not be counted as urban areas according to the U.S. Census Bureau. However, the author has seen, through personal experience living in the study area, that residents who live within the town limits may have different experiences and perceptions of weather events than those who live outside of the town limits. Therefore, urban versus rural was delineated by those that lived within the town limits (city) and those that did not (rural) for the purposes of this study. All U.S. Census demographics were obtained from the 2010 Summary of Population and Housing Characteristics for each state, available from census.gov.

a. Defining a blizzard

Comparing the official blizzard definition to the survey responses, the Dakota residents have a relatively accurate definition of the term. The majority mentioned snow and wind, and slightly less than half touched on the loss of visibility (Table 3.2). The main responses that included snow used descriptions such as "blinding snow," "heavy snowfall," or "snow piling up faster than the plows can keep up with." Some respondents also mentioned snowfall amounts, such as a 48-year old male who described a blizzard as "more than average snowfall combined with high winds, freezing temperatures, and limited visibility. snowfall accumulations of over 12-24 inches."

Temperature is mentioned in nearly one-quarter of the responses, and close to one in five people discuss road conditions or the disruption of services. One response from a 55-year old male encompasses much of what was expected based on the author's experience: "blinding snow and wind that accumulates enough to stop traffic and strand people in their homes." Disruption of services and travel restrictions were sometimes the sole focus of the definition. For example, one 59-year old female defined a blizzard as "cannot drive or advised by police not to drive or bad roads." Another defined a blizzard as "complete shutdown of roads, schools, offices, businesses, etc." While the official definition contains a specified minimum duration, few people included duration in their definition. If mentioned, it was described as "for an extended period" or "for a long duration."

Table 3.3 lists the p-values for the demographic comparisons. Females were significantly more likely (p=0.096) to mention disruption of travel and services in their blizzard definitions than men. Rural residents exhibited higher frequencies when mentioning all codes except disruption of travel and services. The only component that showed a significant difference, though, was wind (p=0.090). The education level comparison mirrors the city/rural comparisons with respondents holding at least a Bachelor's degree more frequently mentioning all components except travel and service disruption. Wind was also significant for education level with those holding at least a Bachelor's degree more likely to mention it than those with less than a Bachelor's degree (p=0.087). It does not appear as though occupation, homeplace, or income have a significant impact on how people personally define a blizzard as none of comparisons were significant.

b. Experiences

When asked about their most recent experiences, information on demographics, duration, and consequences was requested. Some gave just the basic demographic information such as age and location, but most expounded on their experience and the consequences. The most commonly discussed consequences were disruption of service/travel issues and demographics with close to half discussing the weather conditions (Table 3.2). A typical response included demographic information, duration of the storm, difficulty driving, and closures. For example, 55-year old male who has lived in the area his entire life described his most recent experience as:

> It was Sunday and it was about 40 below zero and it snowed all day and it had started during the night sometime. I work for state government and work is never closed but it was closed until noon on Monday and should have been closed longer. I had to have someone pick me up because I live in a twin home complex with a private drive off of the street and it was not plowed but I needed to get to work since it was April 15th and I work for the State Tax Dept. by midafternoon the temperature had returned to normal and most of the streets were opened either by being plowed or snow melted enough.

Becoming stranded or being snowed in was another commonly seen component of blizzard experience. The phrase "snowed in" accounted for twenty-five of the thirty-eight utterances for shelter in place.

Demographic comparison significance can be found in Table 3.3. When comparing men versus women, the only significant difference was found with loss of services in which women showed a higher frequency than men ($p=0.097$). For occupation, hazard professionals were significantly more likely to include shelter issues in their experience description than non-professionals ($p=0.100$). The only significant

difference in education level was found with descriptions of weather (p=0.075) which was more commonly mentioned by those with at least a Bachelor's degree. Respondents with below average homeplace were significantly more likely to mention sheltering concerns (p=0.044) and demographic information (0.066) than those with above average homeplace. Living in the city versus the country and income showed no significant differences between groups when describing blizzard experience.

c. Community Leaders

Residents were relatively satisfied with the community leaders on the issue of road maintenance. On a scale of one to five (one being poor performance and five being excellent performance), the leaders rated 3.51 for salting roads and 3.77 for promptly reopening roads. Plowing of the emergency routes was the highest rated at 3.96. As might be expected, the plowing of side streets was given the lowest satisfaction rating with a 2.88. Responses to this question were also the only one of the four on community leader satisfaction in which those responding "poor" was the second most common response behind "neutral/no answer."

More female respondents rated clearing the side streets as poor than the male respondents. The men, on the other hand, more frequently rated road maintenance as excellent (Figure 3.2). Comparing occupation shows non-professionals more likely to rate their community leaders as excellent in all matters of road maintenance except for salting the roads. Non-professionals were also more likely to rate clearing of the side streets as poor (Figure 3.3). Rural residents more frequently believed power outages were likely during a blizzard and more often rated the community leaders as both

excellent and poor on side street maintenance, while city residents rated their community leaders higher on all other aspects of road clearance (Figure 3.4).

Respondents with a lower level of formal education exhibited a higher frequency of satisfaction (excellent rating) with clearing of emergency routes, salting roads, and re-opening the roads while also being more likely to say their leaders were poor on clearing side streets (Figure 3.5). Those that have lived in the area for at least half their lives were less satisfied with clearing of the side streets. Residents with a lower homeplace appear to be satisfied with how their community leaders respond to blizzards (Figure 3.6). Residents earning less than $50,000 a year were more satisfied with their community leaders on clearing of emergency snow routes and less satisfied on clearing of the side streets. Those earning at least $50,000 a year were more likely to rate clearing of the side streets, salting and re-opening of roads as excellent (Figure 3.7).

When asked to explain what they felt their community leaders could do to improve, a little more than one in four responded with "nothing," "they are excellent at their job," or "they do the best they can" (Table 3.2). However, clearing and maintaining the roads was the focus of most suggestions for improvement. For most people, the issue is keeping the side streets cleared and preventing the roads from icing over. Another problem is where the plows pile the snow. As one resident put it, "snow is plowed and pushed in the center of the streets. You cannot see over to turn corners—very dangerous." A 63-year old female, who identified as white/non-hispanic, was the only respondent to mention the issue of Native versus non-Native lands by saying that they should "replace all community leaders, roads where native americans live don't get plowed."

While just 7.1% of the respondents suggested improved communication, half of those mentioned a desire for a website or app to monitor the plows, so they can have the "ability to see where snow plows are currently and when they should be by your house." Others discussed the commonality of storms in the area (i.e. "I live in South Dakota and expect winters to be bad. Wusses should move south!") and the importance of personal preparation (i.e. "people in the area should be prepared for a blizzard by having food supplies on hand and water").

None of the demographic comparisons for community leader improvement were significant except for homeplace in which those with below average homeplace were more likely to say nothing needed improvement (p=0.0.58, Table 3.3).

d. Preparing for a watch versus a warning

Because of the low counts for car preparation in most cases (counts less than five), home and car preparation were combined for analysis. However, home preparation was also analyzed separately because it met the criteria for significance testing. When preparing for a blizzard watch versus a blizzard warning, the most common concern was ensuring that the home and car were prepared (Table 3.2). For a blizzard watch, actions to prepare the home account for 56.1% of responses while preparation for home and car combined was mentioned in 67.5% of answers. For blizzard warnings, 50.8% of the replies mentioned preparing the home while 61.5% mentioned preparing the home and car. Preparing the home meant making sure that there is enough fuel for the generator or fireplace, making sure there is food and water, and ensuring that all necessary equipment is ready and available. One resident's response covers most of the actions described by various respondents in preparing their home when he said:

> Gather all the flashlights and place them in a known spot in each room. Kerosene lamps ready. Store water. Buy batteries, canned goods, propane, dry good, and other foods. Ensure snow removal equipment is ready and has fuel. Prepare snowshoes and cold weather gear.

When it comes to the car, preparation involved making sure it has gas and emergency kits and moving the car either off the street or into the garage.

The other main concerns when preparing for a blizzard are limiting or halting travel and monitoring the weather and road conditions. Many of the residents of North and South Dakota take the same precautions for both blizzard watches and blizzard warnings, especially in regards to getting their home and car prepared for the storm. Where the main differences tend to occur is the concern for their family and animals. The need to stay home, limit travel, and ensure the family and animals are safe become more important when preparing for a blizzard warning than for a blizzard watch (40.2% compared to 11.4%). For some, checking on family only becomes part of the plan when the warning is issued, as said by a 38-year old male: "no different than a watch other than to make sure all family is in a safe place." Around 14% of those responding to these questions reported taking no actions to prepare for either a watch or a warning.

Results of the significance test for demographic differences are listed in Table 3.3. Women were significantly more likely to mention that they will monitor the road and weather conditions when a blizzard watch is issued ($p=0.015$). When preparing for a blizzard warning, men were more likely to mention preparing the home ($p=0.018$) and preparing both the home and the car ($p=0.004$). While men also mentioned preparation activities more often for a blizzard watch, it was not significant. Hazard professionals

more commonly listed concerns with travel and road conditions when preparing for a blizzard warning (p=0.060).

Rural residents showed more preparation than city residents when a blizzard watch is issued with significantly more rural residents preparing the home (p=0.029). However, the issuance of a blizzard warning showed no significant difference in preparation actions. With a warning, though, rural residents were more likely to monitor the road and weather conditions (p=0.090) and to show more concern for family and animals (p=0.022). Education level was not significant for watch preparation, and it was only significant for blizzard warnings with the concern for travel and road conditions where those with more formal education mentioned travel and road condition more frequently (p=0.012). Once again, homeplace and income showed no significant differences when preparing for a watch or a warning.

e. Preparation by ranchers and farmers

Ensuring the welfare of the animals, whether livestock or outdoor pets, is the main concern for nearly 90% of the ranchers and farmers (Table 3.2). This means they "make sure feed and water are accessible" and "put them in the barn or corral." One woman in the area who is fifty-four years old and has been living in the area for less than twenty-five years, responded that she would "rent her land to others" in the event of a blizzard. When it comes to the crops, there is not much that can be done, and this is the main component for the category "nothing." For those that mentioned crops in general, the response was that crops are on their own and not much can be done if the storm hits before harvest. Others said they did nothing because it was just part of being a rancher.

A 22-year old female encompassed these sentiments of crop resilience, animal welfare, and being a rancher:

> There is no way to protect crops especially but the livestock would be ok, they have shelter belts and barns to go to and also they are very very amazing strong animals, if there is a death or a lot then it is just a loss and that is the game you play as a rancher…just like gambling and crops in the summer with hail. But if it's calving season, you for sure keep the calves and mama in the barn and go out to check on them very very very very regularly…

The comparison between city and rural residents was the only demographic comparison that produced a significant difference in the code frequencies (Table 3.3). While this question was targeted to those currently living on a farm or a ranch, twelve of the ninety-one city residents responded by saying what they did when they used to live on a farm. Because of the large difference in city respondents versus rural respondents, those living in the country were significantly more likely to mention the need to take care of the animals ($p=0.000$). However, if the population of city residents only included those twelve who previously lived on a farm, the difference was not significant.

4. Discussion and Conclusions

The respondents were mostly white /non-Hispanic residents who have lived in the area for approximately half of their lives, and two-thirds earn at least $50,000 per year. Experience with blizzards is reasonably high in the Dakotas as most have lived through at least five blizzards in their lifetimes. Most of the survey respondents lived in the city, speaking to one of the limitations mentioned earlier that online surveys can miss some of the more isolated residents. The respondents also exhibited higher levels of formal education with most having at least a Bachelor's degree, and women responded at a higher rate than men. When asked to provide their personal definition of what constitutes

blizzard, the respondents were fairly close compared to the official definition with frequent mentions of snow, wind, and visibility. Overall, as Adger et al. (2016) suggested, the residents of North and South Dakota have higher levels of preparation overall coinciding with their extensive knowledge and experience.

Disruption of services and road conditions were a common thread across all of the coded questions except rancher/farmer preparation activities. When discussing experience, the closure of services was among the topics most likely to be mentioned as was being "snowed in." While satisfaction with the community leaders was moderate in the Dakotas, the area in which most people felt their leaders needed to improve was in keeping the roads cleared and safe for travel, especially the side roads. Women, non-hazard professionals, rural residents, those with more formal education, those with a higher homeplace, and those earning less than $50,000 were all less satisfied with their community leader responses, particularly with the clearing of the side roads.

Preparation for blizzard watches and blizzard warnings involves monitoring the conditions to see if travel needed to be limited or stopped all together, seeing if schools would be closed or maybe calling into work to say they may not be able to make it in. This was more of a concern with a blizzard warning than with a blizzard watch, which is expected because of the more severe nature of a warning. Ensuring the welfare of the animals by either getting them to a shelter or giving them food and water were, of course, the main issue for farmers and ranchers. A few said they do nothing because they cannot protect their crops or they believe their animals to be resilient enough to care for themselves.

Though not significant, women were more likely to mention wind and snow when defining a blizzard while men more commonly mentioned the loss of visibility and a drop in temperatures. However women were significantly more likely to include the loss of services and travel as part of their definition. When discussing experience, women were again significantly more likely to mention the disruption of services. Female respondents were also more likely to include monitoring conditions with the onset of a blizzard watch while men were significantly more concerned with preparation when the watch becomes a warning.

Hazard and disaster literature has shown that women are usually more concerned with taking care of the family, which can be seen here. Loss of services included not just the closing of roads, but there was also concern with schools and businesses being closed due to the snow. Because women are generally seen as the caregivers, the closing of schools could mean they must either call in to work or find a secondary daycare for their children. By monitoring the weather and roads, women can begin to prepare in advance in the event the situation begins to worsen. Men, on the other hand, are generally found to be the ones concerned with taking care of the community and their homes. When a storm is coming, this means making sure there are enough supplies on hand and ensuring the car and snow removal tools are accessible and ready.

Hazard professionals are expected to have more knowledge of the phenomenon, and this may translate into higher levels of preparation and satisfaction with how the community leaders respond to blizzards. While hazard professionals were more likely to include the official components of a blizzard in their definitions, they were not significantly more likely to do so. They were also not significantly more likely to discuss

preparation activities for either a watch or a warning, though a higher percentage of professionals did mention preparation. The only codes hazard professionals were significantly more likely to mention were issues of shelter when discussing experiences and issues with travel and road conditions for blizzard warnings.

Although it was not significant, hazard professionals were more likely to discuss areas in which community leaders need improvement, such as road maintenance. Most of respondents labeled as hazard professionals were in the medical field. Doctors and nurses deal with accident victims that, during blizzards, may have occurred because of poor road conditions, poor visibility at intersections from snow piles, or inefficiency of road closures. As a result, they may feel that their community leaders need to better deal with the roads in an effort to reduce the injuries or fatalities that may result from mismanagement. Some of the respondents identified as non-professionals are retired persons but were not asked to identify their previous occupation. It is therefore possible that some of those included in the non-professional group were actually retired hazard professionals. Future surveys will ask for this information.

As was mentioned in the introductory section, the research on rural versus urban communities suggests a more complex relationship that can also be seen with this survey. Rural communities can be viewed as more vulnerable because they are more removed from the resources and agencies responsible for blizzard response, but they are also more self-reliant and often have stronger ties with their neighbors. Rural residents did view a power outage as more of a concern than city residents did. Wind was a major component of blizzard definitions for rural residents more than for city residents. In rural areas, there is not as much protection from the wind as you might find in cities or towns. With open

spaces and the occasional wind break, winds can become stronger in the country and may increase the chances of power lines falling or breaking. Although cities can increase winds by funneling it through narrow spaces, the wind may not be as likely to impact the power lines.

Living in town makes it easier to get to the store or to work because the residents live closer to those locations. Residents living in the country must travel farther, and they may have to drive on unpaved roads. There are also fewer places to seek shelter in a rural setting, with homesteads farther apart than would be seen in town. Lack of protection from the wind is a concern for travel as well because of the potential for larger snow drifts. Living farther from the resources, rural residents were more likely to begin preparing for the storm earlier and keep an on eye on the weather than their city counterparts. With livestock and family more spread out (or in town for work), rural residents were also more likely to make sure their families and animals were in shelter and safe when a blizzard warning is in effect.

Comparisons of education level yielded significant results on the inclusion of wind the their definition, mention of weather when discussing experience, and road conditions with blizzard warnings, where these three things were all mentioned more frequently by those with at least a Bachelor's degree. Though not all were significant, respondents with more formal education were more likely to include the main components of the official blizzard definition. People with secondary and advanced degrees have more exposure and access to information through the internet and television as well as through the general education courses required at the university level.

Education level had no significant impact on preparation of the home and car for either a blizzard watch or blizzard warning.

Education level is also generally connected with income, as those with advanced degrees tend to earn more than their counterparts. With higher income, residents would have more access to resources and may not be as concerned with roads and schools closing because of the potential to access and mobilize resources in a shorter amount of time. They would also have the ability to keep more supplies on hand and may not have to be as worried about preparing for the storm as far in advance. However, in this region and as was found on the survey, some of the highest reported incomes were those working as ranchers, government employees, or in the oil fields with their highest level of education an Associate's degree. Income, though, showed no significance in any of the responses with the survey presented here.

Homeplace, because it is a combination of age and residence time, can be used a proxy for place attachment. Because place attachment is strongly tied to length of residence, a higher homeplace could indicate stronger place attachment. As was discussed previously, stronger place attachment has been shown to be tied to pro-environmental behavior. In the case of community leader response to blizzards, this may be interpreted as a desire to see that response improve. This was seen here as those who have lived in the area for more of their lives were less likely to suggest that their community leaders needed no improvement. Those that have lived in the area for a shorter amount of time also may not have had the experiences with poor response that longer-term residents may have. It is possible that those with a lower homeplace moved from another region that experiences blizzards and this new home responds better than

their previous home. However, they were not asked where they lived previously or if they had any blizzard experiences in previous locations. This may be included in future work.

Caution must be taken when applying these results to the Northern Plains or the United States as a whole. People who live in areas where snow is not a common occurrence may have much difference responses to questions about blizzard definitions and preparation because they have less experience. Caution should also be taken because the use of online surveys cannot guarantee that a representative sample of the population of interest is obtained, as evidenced in this study by the overrepresentation of socioeconomic groups such as females, those with bachelor's degrees and the elderly compared to the basic Census demographics of the Dakotas. As with any research that requires remembering experiences, memory bias is a concern. Certain details of their experience may be forgotten or time may have clouded their memory. Another limitation with the survey data presented here is a potential disparity between current living situation and location of experience. While the resident may now live in town, their last blizzard experience may have occurred while they were in a rural setting. Without a distinction identifying it as a rural experience, their story would be counted as urban instead of rural. An example of this can be seen with the question on farmer/rancher preparation. Twelve respondents identified through their answer that, despite currently living in town, they once lived on a farm, though none mentioned how long it has been since moving to town.

With nearly 95% of the respondents experiencing at least five blizzards in their lifetimes, it is possible that their experience with blizzards is overcoming the various

demographic differences that previous hazard literature has shown to be important. More work will need to be done to see if this is indeed the case. However, the survey results presented here do appear to indirectly support the contributions of resource mobilization and chaos theory to hazard and disaster research by showing the importance of access to services and having supplies on hand in advance despite unknown outcomes. By applying existing knowledge on preparation and perception to blizzards, the respondents in this research showed that the ways in which people respond to, prepare for, and perceive hazards may vary depending on the hazard as well as their socioeconomic positioning, social/community ties, and experience. It also brings attention to a hazard that can cause significant impacts to large areas but is underrepresented in the literature.

5. Acknowledgements

The survey administered in this study was approved and supervised by the Oklahoma State University Institutional Review Board, approval AS-15-115.

6. Appendix

3.A: Survey instrument administered to the residents of North and South Dakota aged 18 and older.

Perception

1. How do you define a blizzard?
2. In your lifetime, how many blizzards have you experienced?

0 1 2 3 4 5 or more

3. On a scale of 1 to 5, with 1 being not a problem at all and 5 being a major problem, how much of a problem do you feel blizzards are in your area?

No Problem Major Problem

1 2 3 4 5

---

4. When did you last experience a blizzard (month and year)?
5. Provide details on the last blizzard you experienced. Include information such as where you were, how old you were, how long it lasted, and any consequences (i.e. lost power, snowed in, work/school closed).

6. One a scale of 1 to 5, with 1 being not likely and 5 being very likely, how likely do you think it is to have power outages during a blizzard?

Not Likely				Very Likely
1	2	3	4	5

7. Pipes freezing?

Not Likely				Very Likely
1	2	3	4	5

8. If you lose power during a blizzard, how long does it usually take before it is restored?

<12 hours 12-24 hours 1-2 days 3-4 days 5-6 days >1 week

9. What do you feel is the most dangerous aspect of a blizzard (Choose one):

Ice/snow Wind Cold Loss of visibility Pipes freezing Loss of power

---

On a scale of 1 to 5, with 1 being poor and 5 being excellent, rate the performance of your community leaders on:

10. Salting the roads to prevent icing

Poor				Excellent
1	2	3	4	5

11. Plowing the emergency snow routes

Poor				Excellent
1	2	3	4	5

12. Plowing the side streets

Poor				Excellent
1	2	3	4	5

13. Restoring power when lost

Poor				Excellent
1	2	3	4	5

14. Timely re-opening of closed roads

Poor				Excellent
1	2	3	4	5

15. For any areas you feel the community leaders could do better, explain what you feel should be improved and how?

Preparedness

16. Where do you get your weather information (check all that apply):

TV news Internet Family/Friends National Weather Service Social Media Other (please explain)

17. When a blizzard hits, where do you go for assistance (check all that apply):

Family/Friends Neighbors Police/Fire Government (i.e. Red Cross) No One Other (please explain)

18. Do you know how to shut off the water valves in your home in the event your pipes burst?

Yes No

---

19. Please explain what actions, if any, you take when a Blizzard Watch is issued?

20. Please explain what actions, if any, you take when a Blizzard Warning is issued?

21. If you live on a farm or ranch, explain the actions you take to protect any crops or livestock in the event a blizzard is forecasted.

---

22. Which of the following actions do you take in the winter to protect against damage/harm to you or your property during a blizzard (check all that apply):

Put snow tires on your vehicle Winterize your car(s) Restock emergency kits, food, fuel in the home Restock the emergency kits in the car Keep the gas tank of your vehicle at least ¼ full at all times Install storm windows or plastic over the windows Create a family plan in case of separation during a storm Have the heating (furnace or fireplace) inspected and fixed if necessary Have the roof inspected for strength and drainage (in case of heavy snows and potential leaking when snow melts) Develop a neighborhood plan (i.e. who will help who, sharing of supplies) Leave faucets on a slow trickle to prevent the pipes from freezing

---

23. Which of the following supplies do you keep in your home in the case you become stranded by a blizzard (check all that apply):

Back-up generator/alternate fuels Bottled water Non-perishable food Blankets Battery powered radios Flashlights Extra batteries Weather radio First aid kit Shelter for outdoor pets/animals Carbon Monoxide detectors

---

24. Which of the following supplies do you keep in your car(s) when traveling in the winter in case you are stranded by a blizzard (check all that apply):

Bottled water Non-perishable food Blankets Coats/hats/gloves Kitty litter/salt Shovel Flashlights Battery-powered radios Extra batteries First aid kits Flares/emergency flags Jumper cables Ice scraper Phone charger/charged cell phone Tow chain

---

25. Which of the following actions did you already know you should do in the event you become stranded in your car during blizzard:

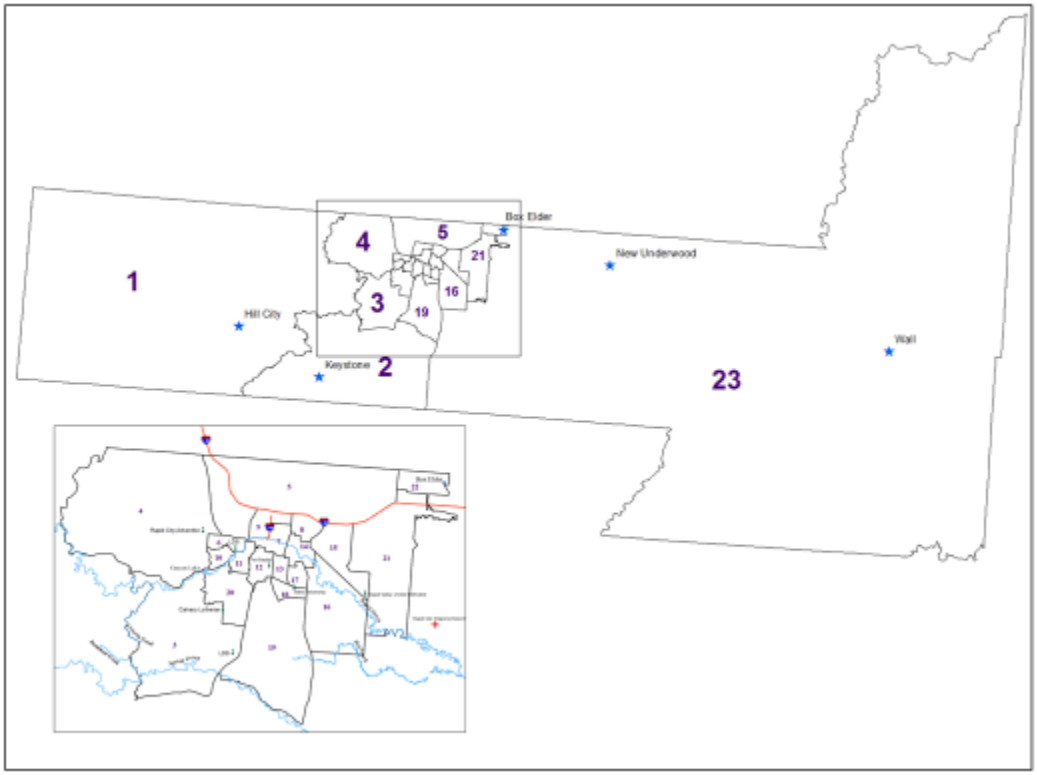
Use hazard lights, flares, and/or emergency flags Run your car only 10 minutes per hour with your windows openMove to maintain your body heat but not too much so as to cause over-exertion If traveling with a partner, alternate who sleeps

Remain hydrated Only use car or battery operated products when necessary to prevent battery drainage Use your interior lights at night to allow rescue workers to better see your vehicle Remain the vehicle until the storm passes

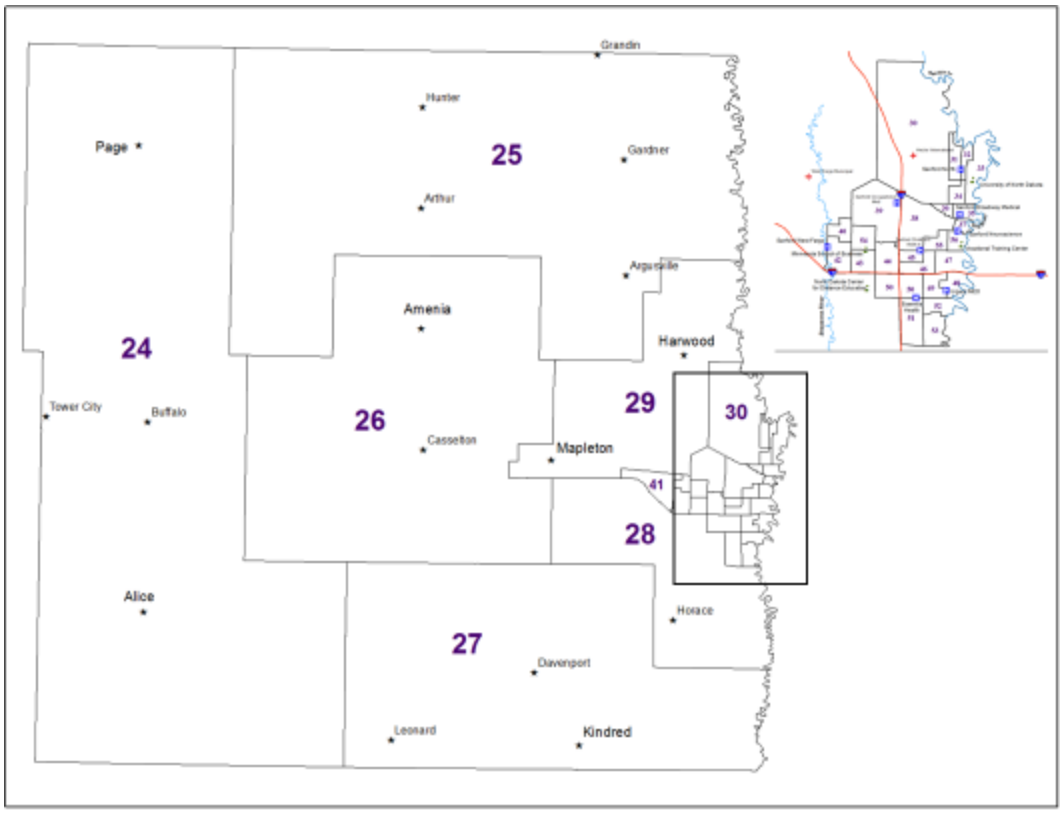
Use rocks or branches to spell out HELP or SOS on the snowy landscape to help aerial crews find you Keep your tank at least ¼ full at all times

Demographics

26. The map below show the census tracts for Pennington County, South Dakota. If you live in Cass County, North Dakota, please skip to question 27. If you live in neither, please skip to question 28. Which number indicates the area of the county where you live (if you live within the boxed area of Rapid City, see the second map):



27. The map below show the census tracts for Cass County. Which number indicates the area of the county where you live (if you live within the boxed area of Fargo, see the second map):



28. City/town or Rural:

City/Town Rural

29. How long have you lived in the area:

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30. Sex:

M F

31. Age:

32. Marital status:

Single Married Widowed Divorced Separated

33. Race/Ethnicity:

White/Non-Hispanic Hispanic African American Asian Pacific Islander Native American 1 or more ethnicities (please specify)

34. Education:

Less than High School High School or Equivalent Some College Associate's Degree Bachelor's Degree Advanced Degree

35. Annual household income:

<$20,000 $20,000-$34,999 $35,000-$49,999 $50,000-$74,999 $75,000-$99,999 $100,000-$149,999 $150,000-$199,999 $200,000 or higher

36. Occupation:

Farmer/Rancher Retail Medicine Fire Police
Factory/Industry Oil Government Retired Unemployed
Other (please explain)

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8. Tables

Table 3.1: Survey Respondent Demographic Summary

	Number of Respondents (%)
Average age (n=123)	54.2
Average residence time (n=126)	25.3
Average homeplace (n=123)	0.47
City or Rural (n=125)	
City	91 (72.8)
Rural	34 (27.2)
Sex (n=127)	
Male	50 (39.4)
Female	77 (60.6)
Race/Ethnicity (n=127)	
White/Non-Hispanic	123 (96.9)
Asian American	1 (0.8)
Native American	3 (2.4)
Education (n=128)	
Less than Bachelor's Degree	57 (44.5)
At least a Bachelor's Degree	71 (55.5)
Income (n=126)	
Low (<$50,000)	42 (33.3)
Mid-High ($50,000 or higher)	84 (66.7)
Number of blizzards experienced (n=151)	
0	3 (2.0)
1	1 (0.7)
2	2 (1.3)
3	1 (0.7)
4	1 (0.7)
5 or more	143 (94.7)

Table 3.2: Overall code counts

	Count (Percent)		Count (Percent)
Definition (n=151)		***Watch (n=123)***	
Wind	103 (68.2)	Monitor Conditions	27 (22.0)
Snow	134 (88.7)	Travel/Road Conditions	27 (22.0)
Visibility	71 (47.0)	Prepare Home	69 (56.1)
Temperature	36 (23.8)	Prepare Home/Car	83 (67.5)
Travel/Services	27 (17.9)	Concern for family/animals	14 (11.4)
Duration	4 (2.7)	Nothing	18 (14.6)
Misc	2 (1.3)	***Warning (n=122)***	
Experience (n=135)		Monitor Conditions	21 (17.2)
Weather	67 (49.6)	Travel/Road Conditions	24 (19.7)
Services	104 (77.0)	Prepare Home	62 (50.8)
Livestock	3 (2.2)	Prepare Home/Car	75 (61.5)
Predict/Real	2 (1.5)	Concern for family/animals	49 (40.2)
Shelter	38 (28.2)	Nothing	17 (13.9)
Common/Prep	13 (9.6)	Misc	3 (2.5)
Demo	77 (57.0)	***Ranchers/Farmers (n=33)***	
Misc	12 (8.9)	Animals	31 (88.6)
Community Leaders (n=84)		Nothing	6 (17.1)
Roads	54 (64.3)	Rent Land	1 (2.9)
Closure	6 (7.1)		
Communication	4 (4.8)		
None	23 (27.4)		
Misc	11 (13.1)		

Table 3.3: Fisher's Exact Test P-values for the demographic comparisons

	Gender	Occupation	City/Rural	Education	Homeplace	Income
Definition						
Wind	0.436	0.427	0.090*	0.087*	0.845	0.843
Snow	1.000	0.371	0.758	0.178	0.784	0.268
Visibility	0.718	0.712	0.316	0.726	1.000	1.000
Temperature	0.676	0.529	0.818	0.684	0.530	0.508
Travel/Services	0.096*	0.342	0.430	0.160	0.349	1.000
Experience						
Weather	0.718	0.460	0.691	0.075*	0.858	1.000
Services	0.097*	1.000	0.796	0.390	0.249	1.000
Shelter	1.000	0.100*	0.822	0.168	0.044**	0.193
Common/Prep	n/a	0.757	n/a	n/a	0.766	n/a
Demo	0.581	0.131	0.226	1.000	0.066*	0.704
Community Leaders						
Roads	0.580	0.707	0.412	0.588	1.000	0.848
No Improvement Needed	0.814	0.634	0.611	0.106	0.058*	0.459
Watch						
Monitor Conditions	0.015**	0.180	0.467	0.201	1.000	0.819
Travel/Road Conditions	0.828	1.000	0.629	1.000	1.000	0.846
Prepare Home	0.856	0.460	0.029**	0.595	0.468	0.258
Prepare Home/Car	0.447	0.847	0.140	0.362	0.260	0.331
Concern for family/animals	1.000	0.769	0.343	0.778	0.256	n/a
No Prep Done	0.595	0.443	n/a	1.000	1.000	n/a
Warning						
Monitor Conditions	0.333	0.321	0.090*	0.633	1.000	n/a
Travel/Road Conditions	0.354	0.060*	1.000	0.012**	0.823	0.473
Prepare Home	0.018**	0.855	0.314	1.000	0.592	0.257
Prepare Home/Car	0.004***	0.192	0.547	0.368	0.582	0.254
Concern for family/animals	0.136	1.000	0.022**	0.275	1.000	1.000
No Prep Done	0.269	1.000	n/a	0.178	0.404	n/a
Ranchers/Farmers						
Animal Care	1.000	0.670	0.000***	0.301	0.836	0.268

*Significant at 90% level
**Significant at 95% level
***Significant at 99% level
n/a=Fisher's Exact test not calculated because of counts below 5

9. Figure Caption List

Figure 3.1: Study Area (a) and Frequency of blizzards in the Northern Plains as shown Chapter II (b)

Figure 3.2: Percentage comparisons of sex on questions of community leader response

10. Figures

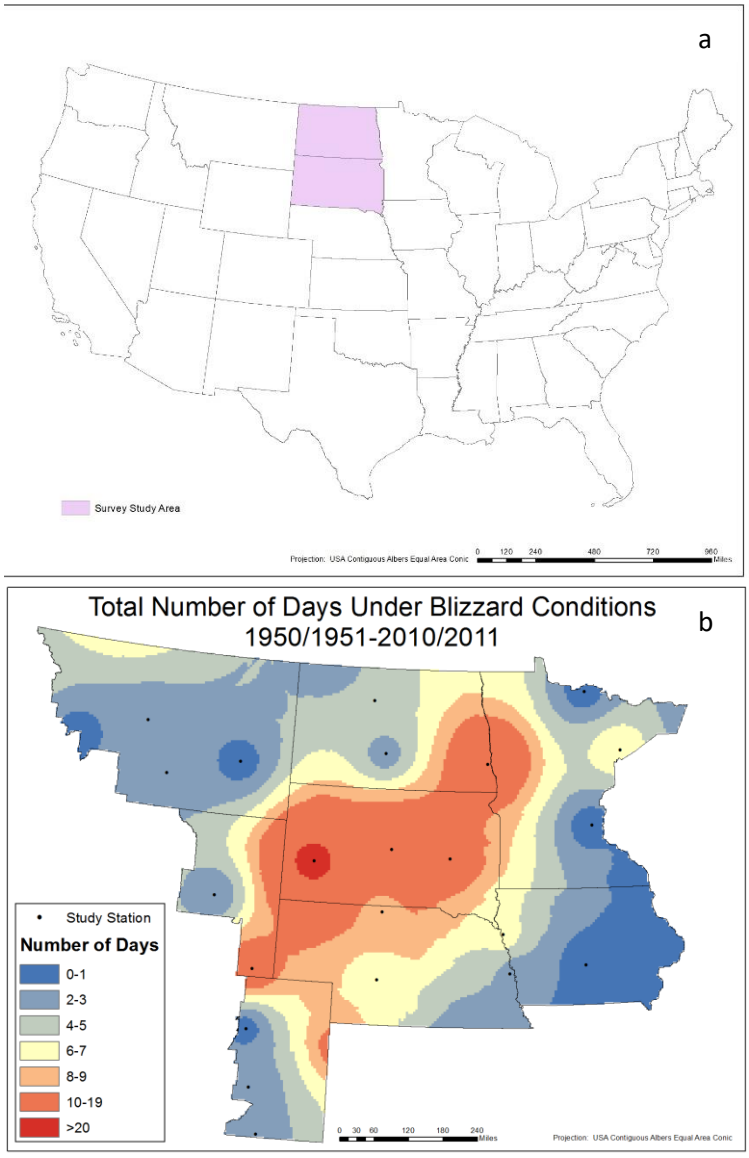

Figure 3.1: Study Area (a) and Frequency of blizzards in the Northern Plains, as shown in Chapter II (b)

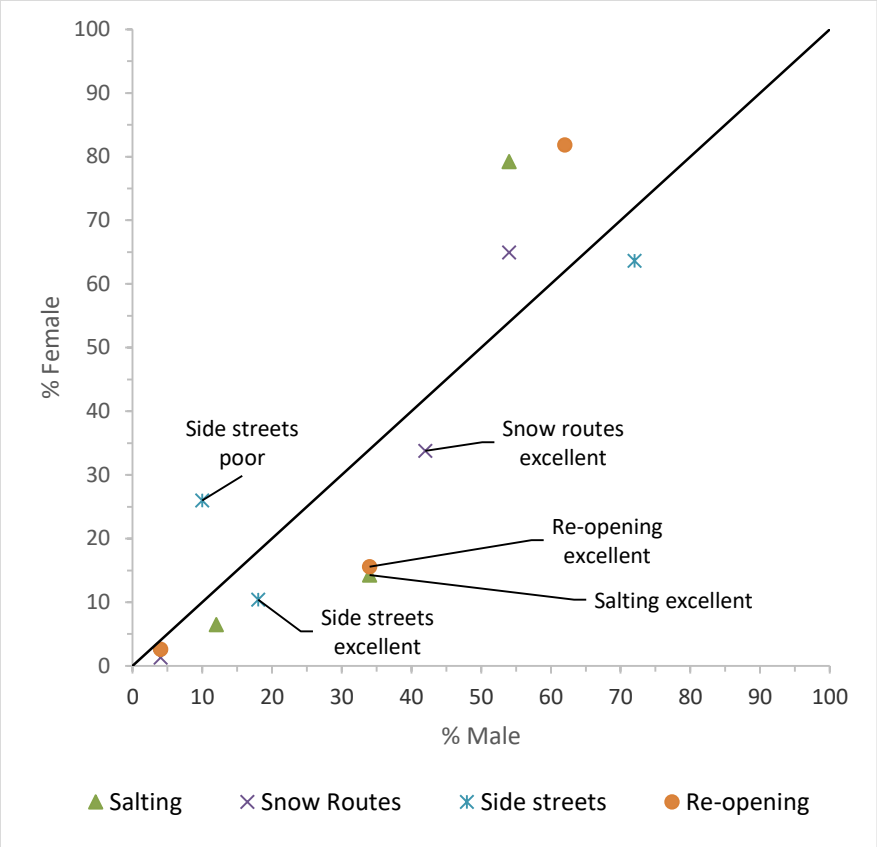

Figure 3.2: Percentage comparisons of sex on perception of community leader response

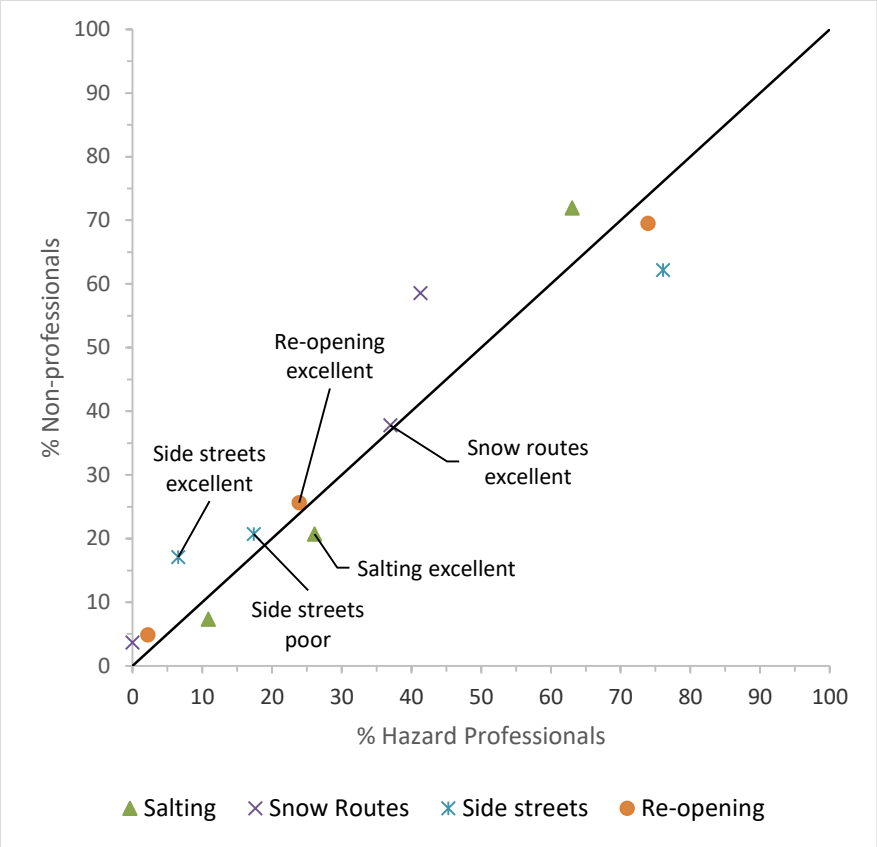

Figure 3.3: Percentage comparisons of occupation on questions of community leader response

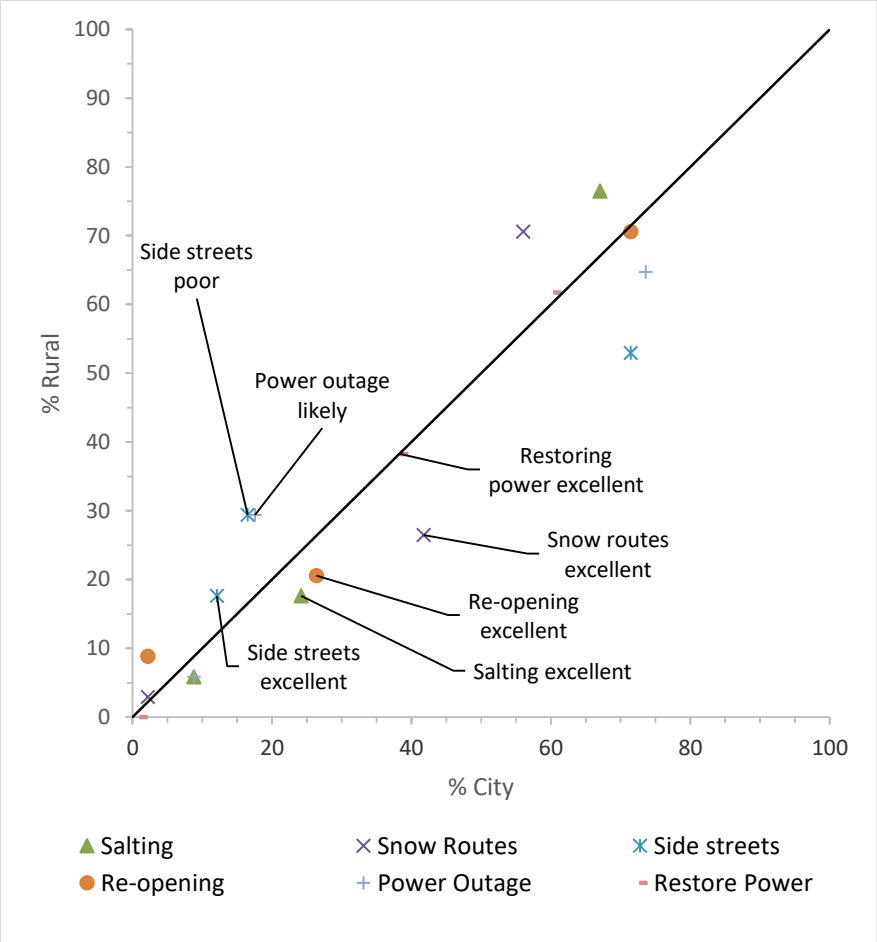

Figure 3.4: Percentage comparisons of city residents versus rural residents on questions of community leader response

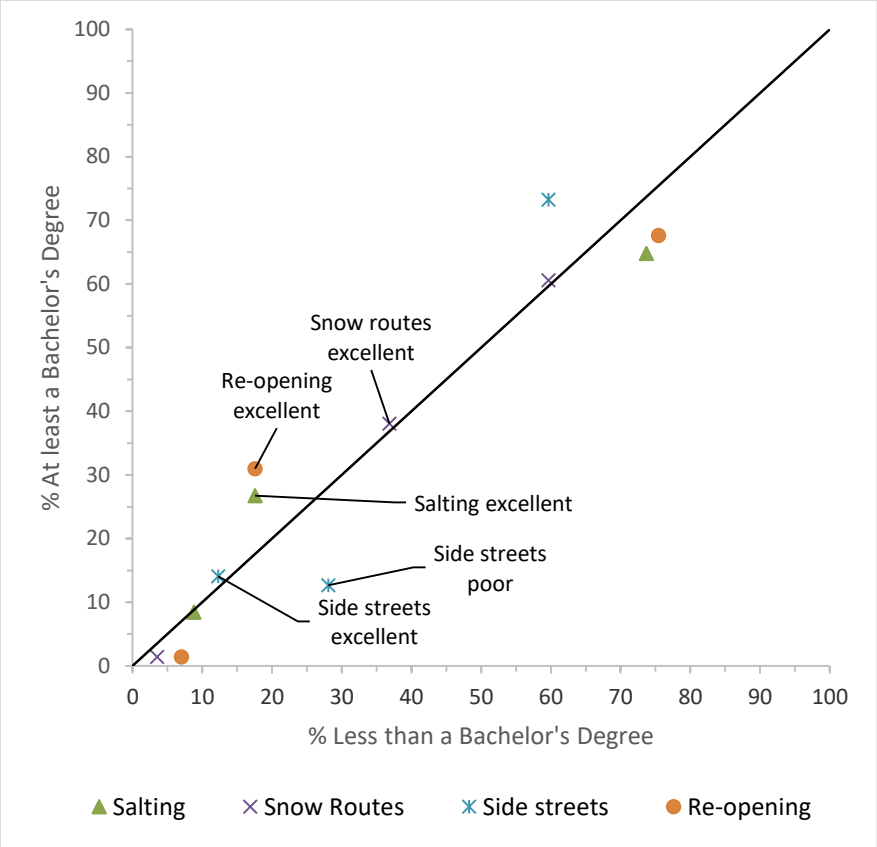

Figure 3.5: Percentage comparisons of education level on questions of community leader response

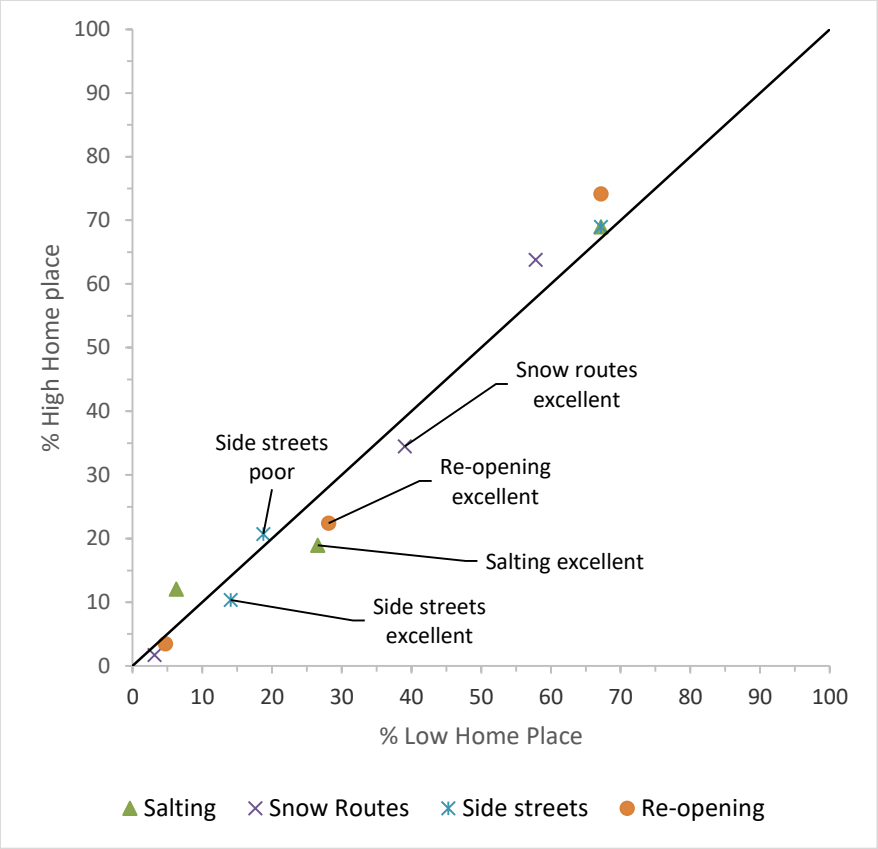

Figure 3.6: Percentage comparisons of homeplace on questions of community leader response

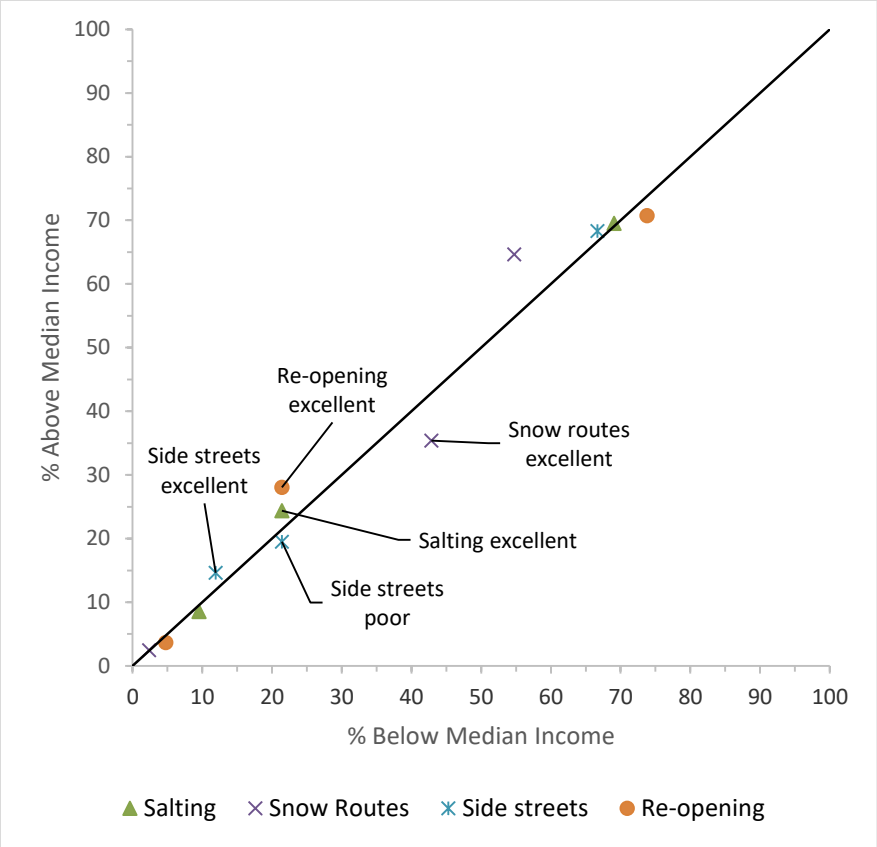

Figure 3.7: Percentage comparisons of income on questions of community leader response

CHAPTER IV

TRACT LEVEL ANALYSIS OF SOCIAL VULNERABILITY AND RESILIENCE TO BLIZZARDS: A CASE STUDY OF CASS COUNTY, NORTH DAKOTA

Authorship and Journals

The title of this chapter, "Tract Level Analysis of Social Vulnerability and Resilience to Blizzards: A Case Study of Cass County, North Dakota," is the planned title for this article, and I propose to be the sole author. Because the research for this article focuses on mapping social vulnerability and resilience at the Census tract level, a journal through the American Association of Geographers (AAG) or specifically dedicated to vulnerability and resilience would be the types of journals chosen. Potential journals for publication of this article would be those such as *The Professional Geographer* (PG) or *Social Science Quarterly* (SSQ). The reason for choosing SSQ is because this is the journal in which Susan Cutter first published the Social Vulnerability Index. A Geography journal such as PG would bring some of the concepts highlighted in this article to the discipline, and it is a smaller journal within the field.

Abstract

Analyzing the social vulnerability and resilience of a community to natural hazards has been a key component of hazards research for decades. However, the studies are typically done at the county level, and social vulnerability and resilience are more localized phenomenon. Indices are also sensitive to the variables chosen. The purpose of this article is to illustrate these points using a method that was created for county-level analysis. Because Cass County, North Dakota has been shown to have high blizzard exposure, it was chosen as a case study. U.S. Census variables at the tract-level were aggregated into either a vulnerability index or a resilience index, and the tracts were then grouped into one of four quadrants. Using either gas or electric heat can make a home both vulnerable and resilient in the event of a blizzard, so these two variables were moved between the vulnerability and resilience indices to compare the differences. Home heating method appeared to have no influence on social vulnerability or resilience, except in the more rural and remote tracts of Cass County. However, it can be seen that social vulnerability is not uniform throughout the county and that resilience and vulnerability are not exclusively opposites.

Keywords: blizzards, social vulnerability, social resilience

Introduction

Hazards are natural events that can be either meteorological (i.e. temperature extremes, hurricanes, blizzards), geological (i.e. earthquakes, landslides), or hydrological (i.e. floods, ENSO) which threaten communities and the things they value. When hazards occur, they can overwhelm the community leaving them unable to cope with the impacts. It is then that it becomes a disaster (Gregg and Houghton 2006). Hazard and

disaster research began with the Department of Defense during the Cold War as the U.S. military and U.S. government wanted to understand how people would react to wartime activities. However, Prince's work on the 1917 munitions explosion in Halifax is said to be one of the first systematic studies of disaster (Quarantelli 1987; Oliver and Hoffman 1999).

Historically, hazards have been the purview of geography while sociology focused on disasters (Cutter 2001), but the field has become increasingly interdisciplinary. There has also been a shift in the paradigm used for hazards research. Initially, the idea was to map the hazard and the people in the hazard zone, determine possible adjustments and perceptions, and figure out the ideal adjustments. The modern paradigm is largely the same, but the need for sociopolitical context has been added (Cutter 2001) because both the causes and consequences of a disaster stem from the social structure and social processes within the community (Kreps 1984). According to a 1997 study, more than half of the existing research in the field was produced between 1977 and 1997 and has expanded to include the importance of context in creation and social vulnerability (Alexander 1997).

For mapping and analyzing the spatial dynamics of hazards and disasters, geography is the discipline at the forefront. Although, finding specific risk areas can be difficult with some storms, such as blizzards. With more people and development moving into hazardous areas and improved spatial analytic tools, geographers are poised to make significant contributions to understanding spatial and temporal trends (Degg 1992; Montz and Tobin 2012). One of the concepts in which understanding patterns is important is social vulnerability and resilience to the hazards, which is mostly studied at

the county level. However, these are a more localized phenomenon, and there is more than one way in which to analyze them. One of these is the calculation of an index using general demographic data or one tailored to a specific hazard. The purpose of this research was to explore social vulnerability and resilience to blizzards at a scale below the county-level for a county in the Northern Plains with high blizzard exposure.

The Northern Plains saw more than $330 million in damages between 1950 and 1989 from winter storms (Changnon and Changnon 1992). Winter storms have been shown to kill 30-40 people with an average of 3.7 catastrophic winter storms (defined as causing more than $1 million insured property loss) a year (Changnon 2007). Additionally, winter weather accounted for 18% of the hazard mortality measured by the Spatial Hazard Event and Loss Database for the United States (SHELDUS) from 1970-2004 (Borden and Cutter 2008). Even in places where severe winter weather is common, a snowstorm can become a disaster (Smith 1992). Because severe snowstorms and blizzards are a relatively common occurrence in the Northern Plains states, the people living there may become complacent which could increase their social vulnerability. However, the commonality of these storms can also increase resilience as residents take the necessary precautions in advance.

The characteristics that make a snowstorm severe depend on the part of the country under examination. For example, snowfall amounts of five inches may be considered an inconvenience for those living in the Northeast but have the potential to shut down cities in the South for days. A few indices have been developed to address these regional differences. One such index is known as the Local Winter Storm Scale (LWSS), and this scale ranks snowstorms based on historical context. The purpose of

LWSS is to show the potential of the storm to cause disruption according to historical snow events in the region (Cerruti n.d.). Similar to LWSS is the Winter Storm Severity Index (WSSI) which uses mapping software to combine the winter storm forecast with other information, such as land use and population, to predict the potential impacts of the storm (Nash and Soroka 2016). However, both of these indices only predict the potential for disruption and do not provide information on the actual societal disruption.

One of the first measures of actual disruption was done by Rooney (1967) in his work on the urban snow hazard. Using seven cities in northern United States, he utilized newspaper articles and public records to develop a hierarchy of disruption based on the impacts to transportation, power, schools, manufacturing, construction, and retail. His scale ranged from first order (the city essentially shuts down) to fifth order (minimal disruption, if any). He found that most of the disruption is found in places that should be highly prepared for heavy snows (Rooney 1967). Building off of Rooney's work, the Rooney Disruption Index (RDI) has been developed by the National Weather Service (NWS). The RDI is designed to predict the actual disruption to services such as schools, transportation, and power caused by a winter storm (Cerruti n.d.).

The final index developed to account for the regional response differences is the regional snowfall index (RSI), which was developed to take magnitude and frequency of snowfall events into account. Doing this allows for an analysis of trends in regionally severe snowfalls. Some research has shown that regionally severe snowstorms have doubled in the last 50 years compared to the previous 60 years (Kunkel et al. 2013) while the higher latitudes can be expected to see an increase in snowfall as the climate continues to change (Kapnick and Delworth 2013). Most of these indices, though, are

designed solely for use by weather forecasters to provide impact forecasts along with the winter storm forecasts. These indices, though, provide just the physical aspect of a community's vulnerability to blizzards. Social vulnerability and social resilience are also important factors to consider.

Vulnerability science, according to Cutter (2003), grew out of cross-disciplinary work and needs to continue to bring together the social and physical sides of the natural system. Social vulnerability became a larger focus in disaster research in the latter half of the 1990s and continues to dominate the field (Montz, Cross, and Cutter 2003), and some argue that it is the key to understanding and reducing risk. However, social vulnerability is dynamic and depends on the geographic scale with the ultimate goal to find the points in the system that need the most attention (Birkmann 2006a,2000b; Queste and Lauwe 2006).

The use of indicators to measure certain parameters has been done since the 1960s, and it is common to combine them into a composite indicator. In disaster research, the most commonly used composite indicator is the Social Vulnerability Index (SoVI). SoVI uses factor analysis to create a measure of social vulnerability (inability of people or societies to cope with and recover from disasters) that can be used at both the national and subnational level in any country (Cutter, Boruff, and Shirley 2003; Cutter et al 2008; Cutter, Burton, and Emrich 2010; Tate 2012, 2013). However, this work was all done at the county level which could be hiding pockets of higher or lower social vulnerability that may be found at smaller geographic areas such as the Census tract.

Many factors can increase an area's social vulnerability to a hazard and/or disaster. The most commonly used for social vulnerability are socioeconomic variables

like those measured by the U.S. Census or American Community Survey (factfinder.census.gov): age, sex, employment (rate and type), race/ethnicity, income, education, vehicle ownership, utilities, age of the home, home value, household size, language, etc. Other variables of interest often found in the literature are roads (i.e. types, access), voting history, per capita services (i.e hospitals, nursing homes), population growth, infrastructure, and urban-rural divides (Morrow 1999; Cutter, Boruff, and Shirley 2003; Buckle 2006; Cutter and Emrich 2006; Borden et al. 2007; Cutter et al. 2008; Yoon 2012). While using indices to measure and report social vulnerability has become a more common practice, there is uncertainty in the calculations that cannot be avoided. Tate (2013) discussed seven ways in which uncertainty can be introduced into social vulnerability indices:

1) method of aggregation

2) choice of variables (can cause bias if some components are not included)

3) error in the measurement of the chosen variables

4) transformation of the data (raw numbers, percentages, ranks)

5) how the data are normalized

6) weighting method (if weighted at all)

7) level of analysis (modifiable area unit problem).

Tate (2012, 2013) further argued that the method of index construction has more of an influence on the outcome than the variables chosen with deductive methods more sensitive to the method of standardization and inductive methods to the scale. Despite the acknowledgment that including perceptions and preparation of the community at risk is important and can reduce social vulnerability (Short, Jr. 1984;

Cutter 2001; Buckle 2006; Tobin and Montz 2009), the inclusion of perception and preparedness data is missing from the social vulnerability index research.

Social resilience has become part of the disaster literature in the last few years because of events such as Hurricane Katrina and the Nepalese earthquake, support for city-level resilience measures, and pressure from stakeholders (Cutter 2016a). While social vulnerability focuses on the system components that increase the chances of loss during disaster, social resilience focuses on those things that increase their ability to cope with the impacts (Cutter 2016b). Resilience can be both inherent (pre-existing characteristics of the system) or adaptive (learning through event), and geography is the discipline through which each are analyzed and combined with their impact on place. While it may appear as though social vulnerability and social resilience are opposites, this is not necessarily the case. Communities and individuals can be both vulnerable and resilient in the face of disaster (Cutter 2016a, 2016b).

As mentioned, there are many factors affecting social vulnerability. It has been suggested that the rise in global population and advances in technology are causing an increasing number of disasters worldwide (White, Kate, and Burton 2001), and vulnerability has been listed as one of the big questions that geographers should be addressing (Cutter, Golledge, and Graf 2002). Also of concern is the likelihood of more frequent extreme events with continued climate change (White, Kate, and Burton 2001; Gutowski, Jr. et al. 2008; Lein et al. 2009; Cuevas 2011), which could mean a higher risk of major blizzards occurring in the future. The rise in extreme events also carries the risk of amplifying factors of individual vulnerabilities such as poverty and hunger (Cuevas 2011).

As Tate (2012, 2013) argued, it is not only the geographic scale that matters but also the method of aggregation and variables chosen. Geographic scale, the localized nature of social vulnerability and resilience, and the relative lack of research on blizzards in this area informed the questions addressed in this article. Because previous research (Heise 2013) showed Cass County, North Dakota (Figure 4.1) to have low to average social vulnerability at the county level and higher levels of blizzard activity, it is used as a case study in which the following questions are examined: What is the geographic trend of social vulnerability and resilience at the tract level? How does the inclusion of different variables change the results?

Methodology

Tract-level data from the 2010 U.S. Census was downloaded from Factfinder.gov at the tract level. This was done because social vulnerability is a local phenomenon (Queste and Lauwe 2006), but some of the indicators of interest are not available at scales below tract level. Variables were chosen from the Census using previous research on social vulnerability indices showing indicators such as age, race/ethnicity, sex, occupation, housing tenure, and financial status (Cutter, Boruff, and Shirley 2003; Birkmann 2006a,2006b; Buckle 2006; Cutter et al 2008; Cutter, Burton, and Emrich 2010; Montz and Tobin 2012; Tate 2012,2013; Cutter, Ash, and Emrich 2014; Cutter 2016a).

In addition to the Census data, locations for various local services (airports, churches, schools, police stations, hospitals, etc.) were collected using the Yellow Pages and geocoded to obtain a per capita count of each service per tract by dividing the number of services per tract by tract population. The services were chosen so they

fit into one of the categories listed by Parfomak (2005) in his report to Congress as critical infrastructure (systems or assets so vital that their loss would be debilitating for the community), focusing on transportation (airports), emergency services (hospitals, fire and police stations), and large gathering sites (churches, community centers/non-profits, libraries, prisons, retirement homes, and schools). The locations of the services were Geocoded into ArcMap using the spreadsheet addresses generated from the Yellow Pages search. Any addresses that did not match were found in Google Earth and their latitude and longitude used to add them to the appropriate shapefile.

The main methods for this paper were adapted from Miller, Johnson, and Dabson (2016). While their work was done at the county level, it was scaled down to the tract level for the study presented in this paper using only variables from the U.S. Census because of time and financial restraints. A higher number of variables was also used here. Indicators were normalized by using the min-max rescaling method (normalized value=[value-minimum]/[maximum-minimum]). Each variable was then divided into a social resilience index or a social vulnerability index in which the included variables were averaged (Table 4.1). This ensured the final index value fell between one and zero. The resulting tract scores were averaged, and each tract was labeled as "high" or "low" relative to that average (above average is "high", below average is "low"). Each tract was then assigned a value of one through four based on the quadrant in which it fell (Table 4.2). Quadrant two is the least ideal (high vulnerability and low resilience) while quadrant four is the most ideal (low vulnerability and high resilience). All variables and factors were given equal weight as there is not yet a clear understanding of how the indicators link

together or how to create objective weighting (Cutter, Burton, and Emrich 2010; Tate 2012, 2013).

For blizzards, the potential loss of electricity becomes a real concern. If the home uses electric heating, the loss of electricity may mean no heat for the home increasing their vulnerability to negative impacts. The use of gas heating and propane can then increase resilience because the loss of electricity may not affect their heating. However, this can become an issue if there is not enough propane on hand to keep the heat running and they are unable to make it into town to obtain more. Because of this, three index comparisons were run: both heating variables included in the resilience index, both heating variables included in the vulnerability index, and gas heating included in the resilience index with electric heating in the vulnerability index. All mapping was done using ArcGIS 10.3.

Results

The county-level analysis by Miller, Johnson, and Dabson (2016) for social vulnerability and social resilience showed Cass County, North Dakota falling into quadrant one (high vulnerability, high resilience). For each map of social vulnerability and resilience, blues indicate higher index values and yellow/light green indicate lower values while the darker green indicates values around average. The range of values for each of the six calculated indices remains fairly close, with little change between them. Including the two heating variables in the social resilience index, both the most resilience and least resilient tracts can be found in and around Fargo (Figure 4.2a, average resilience score 0.326). The least resilient tracts are found near West Fargo and in the downtown area of Fargo, and the track immediately to the southwest is highlighted as the most

resilient track in the county. The northern and northeastern tracks of Cass County also show higher than average resilience levels, while most of the county exhibits moderate levels.

The counterpart to this index, social vulnerability without the heating variables, shows the northeastern and southeastern border tracts of Fargo to be the least vulnerable. The tracts within central Fargo and West Fargo, though, are the most vulnerable (Figure 4.2b, average vulnerability score 0.334). Most of the county is again near or below the average value. The resulting quadrants can be seen in Figure 4.2c. The tracks surrounding the cities of Fargo and West Fargo, as well as some along the state border, fall into quadrant four (low vulnerability/high resilience) when the heating variables are considered a factor increasing resilience. The westernmost tract of the county and those within West Fargo and central Fargo are those highlighted as being highly vulnerable and less resilient.

When switching both heating variables to the vulnerability index, most of the county exhibit higher resilience (Figure 4.3a, average resilience score 0.309). The tracts in central Cass County and those to the north of Fargo showed more resilience when the heating variables are not included. The least resilient tracts remain in West Fargo and central Fargo. The tracts of West Fargo and downtown Fargo remain highly vulnerable (Figure 4.3b, average vulnerability score 0.344). The border tracts in the northeast and southeast remained among the least vulnerable, but the Census tract to the northwest of the city became one of the least vulnerable tracts with the inclusion of the heating variables. In the quadrant analysis of this set of indices, those tracts in quadrant two

(high vulnerability/low resilience) are confined to the city while the tracts in quadrant four (low vulnerability/high resilience expand northward (Figure 4.3c).

The final index calculation included the gas heating variable with the resilience index and the electric heating variable in the vulnerability index. The least resilient tracts remain in West Fargo and downtown Fargo with most of the eastern two-thirds of the county showing higher resilience (Figure 4.4a, average resilience score 0.317). The highly vulnerable tracts are also confined to the city with only those border tracts in the northeast and southeast the least vulnerable (Figure 4.4b, average vulnerability score 0.340). Most of the county exhibited below average vulnerability when only the electric heating variable is included in the vulnerability calculation. The resulting quadrant map (Figure 4.4c) is almost exactly the same as that shown in Figure 4.2c.

Only three tracts changed between the three quadrant maps. The westernmost tract is included in the high vulnerability/low resilience tract when the heating variables are both in resilience or when just the gas heating variable is included in resilience. If the heating variables are included in the vulnerability index, resilience remained low but vulnerability decreased for that tract. The second tract that changed was the northernmost tract, which switched between high vulnerability/high resilience and low vulnerability/high resilience. As with the westernmost tract, the decrease in vulnerability came when both heating variables were included in the vulnerability index. The final tract showing a dependence on heating type was one of the tracts within the city of Fargo along the state border. It did not matter if both heating variables were with the resilience index or the vulnerability index for this tract as it was in the high vulnerability/low resilience quadrant for both. Splitting the heating variables, though, decreased the

vulnerability and it became part of the low vulnerability/low resilience quadrant when gas heating was considered resilient and electric heating vulnerable.

Discussion and Conclusions

Analysis of the social resilience indices shows that much of Cass County is near or above the tract average in each of the three calculations. This is especially true when the resilience index either does not include any heating variables or includes gas heating only. Minorities and those living in poverty are discussed in the literature as some of the most vulnerable populations, which can be seen in both the lower resilience and higher vulnerability scores in the downtown and city center regions where these populations are higher. The higher resilience tracts in Cass County are characterized by larger average family size, more formal education, higher median incomes, and more carpooling. With these characteristics, people living in these parts of the county have more people to rely on (either family or members of the carpool) and may have better access to resources through those connections and their higher income level.

Comparison of the three index quadrants indicates that the method of heating does not have much of an impact on resilience in Cass County. However, it did have some impact on the vulnerability levels of three of the county's tracts. In each of the three quadrant analyses, moving one or both of the heating variables into the vulnerability index decreased vulnerability in those three Census tracts relative to the county tract average while leaving their resilience levels unchanged. For the larger tracts in the west and north parts of the county, the inclusion of both heating variables caused the decrease in vulnerability relative to the average. These tracts are more rural and less densely populated. Residents in these parts of Cass County may use a combination of electric and

gas heating in their homes, such as using a propane or natural gas generator as a back-up to their electricity. This redundancy of heating sources allows the heat in the home to remain on even if the power goes out and does not return for an extended period of time. However, vulnerability may remain a little higher because blizzard power outages can last for weeks in the rural areas. If the house does not have enough gas on hand or does not have the ability to obtain more, they run the risk of running out before the power is turned back on.

The third tract did not change until only the electric heating variable was switched into the vulnerability index. This tract is located in the city Fargo along the border between North Dakota and Minnesota. Being part of the city and close to downtown may be able to explain why this tract became less vulnerable when including only electric heat. Living in the city, it is more likely that the homes are connected to the city's electrical grid. However, the average score for this tract was just under the county tract average (0.339 compared to the average 0.340). So, while this tract was classified as "low vulnerability" based on the criteria, it was so close to the average that it may still be considered a high vulnerability/low resilience location susceptible to a loss of electricity.

Although the variables used in this analysis can be considered generic indicators of vulnerability and resilience, some can be blizzard-specific. In addition to the heating variables, this can include the elementary school population, single mother homes, reliance on public transit, lack of vehicle access, rural, and primary employment populations. For single mothers and the number of children in elementary school, a blizzard could be more highly disruptive. Schools tend to be shut down in the event of a blizzard, leaving single mothers trying to figure out what to do with their children while

they are at work. If the roads are shut down because of the snow, those that do not have a car or rely on public transportation to get to work must either call in or find another way to get there. Those that work in primary employment (farming, resource extraction) may not be able to work because snow, wind, visibility loss, and/or low temperatures can shut down production/extraction. Rural populations have a higher chance of becoming isolated or stranded because of road closures or power outages from the blizzard, and these issues could last for days or weeks.

The methods used in this article were modified from a county-level analysis that used fewer variables and included data for things not found in the U.S. Census (i.e. 501(c)3 organizations, crime rates, number of police jurisdictions). Miller, Johnson, and Dabson's (2016) paper also analyzed dimensions of vulnerability and resilience in addition to the social component: economic/financial, infrastructure, and physical/environmental. Some of the variables used in this article were used in the other dimensions by Miller, Johnson, and Dabson. For example, they included primary employment in economic vulnerability while mobile home and no vehicle access were counted as infrastructural vulnerability. Further work in this area is planned with the inclusion of some of the non-Census data used in the original method and the division into the various dimensions. However, one must be aware that certain information may not be available below the county level due to privacy or data collection limitations.

Other methods of aggregation or standardization would likely produce different results, but this study shows that smaller geographic levels can indicate more intricate patterns, which supports the argument that social vulnerability and resilience are phenomenon that should be studied at a more localized scale. With slightly different

patterns emerging from the three indices used, the results presented here support the argument that aggregation method and variable choice matter (Tate 2012, 2013). While the county level results from Miller, Johnson, and Dabson (2016) indicated that Cass County exhibited higher levels of both resilience and vulnerability, the tract level analyses show that there are pockets of high vulnerability/low resilience and low vulnerability/high resilience within the county. By using smaller geographic areas and by dividing the variables into resilience versus vulnerability, the index can show which tracts need the most attention and where resources should be focused to increase community resilience. These results also show that locations can be both highly vulnerable and highly resilient (and vice versa) simultaneously, bolstering the argument that resilience and vulnerability are not exclusively opposites.

Social vulnerability and social resilience cannot be fully understood by analyzing static socioeconomic and demographic variables. Knowledge of the risk perception and preparation levels of the people may help local emergency managers see where to allocate resources or improve mitigation measures to better serve their communities. Because numbers are generally the language of business and policy, finding a way to quantify perception, preparedness, and other variables not found in the U.S. Census has the potential to increase the robustness and applicability of social vulnerability and social resilience indices. If planners and policy makers have such measures, a more structured analysis of inequality may be possible, and resources can be focused where they are needed the most. Aggregation of variables into groups such as social and economic components may also help to increase the efficiency of resource allocation. Hazard

specific surveys may be used to tailor the index to the hazard of concern, thus allowing for a more tailored response to each event instead of a "one size fits all" policy.

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Tables

Table 4.1: U.S. Census and American Community Survey variables and the index in which they were used

Variable	Variable Abbreviation	Index
Median Age of the population	MedianAge	Resilience
Population under 5 years old	Under5	Vulnerability
Population under 16 years old	Under16	Vulnerability
Population over 65 years old	Over65	Vulnerability
Female population	Female	Vulnerability
White population	White	Resilience
Native American population	NativeAm	Vulnerability
African American population	AfAmer	Vulnerability
Asian population	Asian	Vulnerability
Hispanic population	Hispanic	Vulnerability
Population living in group quarters	InGroupQuarters	Vulnerability
Institutionalized population	Institutionalized	Vulnerability
Female-headed households	SingleFemaleHome	Vulnerability
Female-headed households with children	SingleMom	Vulnerability
Average size of family	AvgFamSize	Resilience
Rural population	Rural	Vulnerability
Population separated or divorced	SeporDivorced	Vulnerability
Population widowed	Widowed	Vulnerability
Population in elementary school	InElementary	Vulnerability
Population with at least a high school diploma	AtLeastHSDiploma	Resilience
Population with at least a Bachelor's degree	BachelorHigher	Resilience
Population speaking only English in the home	EnglishOnly	Resilience
Population speaking English less than very well	EnglishLessWell	Vulnerability
Population unemployed	Unemployed	Vulnerability
Population carpooling to work	Carpool	Resilience
Population using public transit to get to work	PublicTransittoWork	Vulnerability
Population in primary employment	PrimaryEmploy	Vulnerability
Median Income of the population	MedianIncome	Resilience
Population living in poverty	Poverty	Vulnerability
Population living in mobile homes	MobileHomes	Vulnerability
Homes built before 1939	HomesBuildPre1939	Vulnerability
Homes built after 2010	HomesBuildPost2010	Resilience
Population that rents	Renters	Vulnerability
Population with no access to a car	NoCar	Vulnerability
Homes using utility or gas to heat home	HeatUtilityGas	Resilience/Vulnerability
Homes using electricity to heat home	HeatElectricity	Resilience/Vulnerability
Homes without indoor plumbing	NoPlumbing	Vulnerability
Homes without a phone	NoPhone	Vulnerability
Population with a disability	Disability	Vulnerability
Population uninsured	Uninsured	Vulnerability
Number of airports per capita	AirPerCap	Resilience
Number of churches per capita	ChurchPerCap	Resilience
Number of community centers per capita	CommCentPerCap	Resilience
Number of fire stations per capita	FirePerCap	Resilience
Number of police stations per capita	PolicePerCap	Resilience
Number of hospitals per capita	HospPerCap	Resilience
Number of libraries per capita	LibPerCap	Resilience
Number of prisons per capita	PrisonPerCap	Resilience
Number of retirement or assisted living homes per capita	RetirePerCap	Resilience
Number of schools (all levels) per capita	SchoolPerCap	Resilience

Table 4.2: Quadrant numbers for the social vulnerability and resilience index combinations

Quadrant Number (associated color in images)	Social Vulnerability	Social Resilience
1 (blue)	High vulnerability	High resilience
2 (red)	High vulnerability	Low resilience
3 (yellow)	Low vulnerability	Low resilience
4 (green)	Low vulnerability	High resilience

Figure Caption List

Figure 4.1: Location of Cass County, North Dakota and Fargo

Figure 4.2: Social resilience scores (a), social vulnerability scores (b), and quadrant results (c) for Cass County tracts with both heating variables included in the social resilience index

Figure 4.3: Social resilience scores (a), social vulnerability scores (b), and quadrant results (c) for Cass County tracts with both heating variables included in the social vulnerability index

Figure 4.4: Social resilience scores (a), social vulnerability scores (b), and quadrant results (c) for Cass County tracts with gas heating in the social resilience index and electric heating in the social vulnerability index

Figures

Figure 4.1: Location of Cass County, North Dakota and Fargo

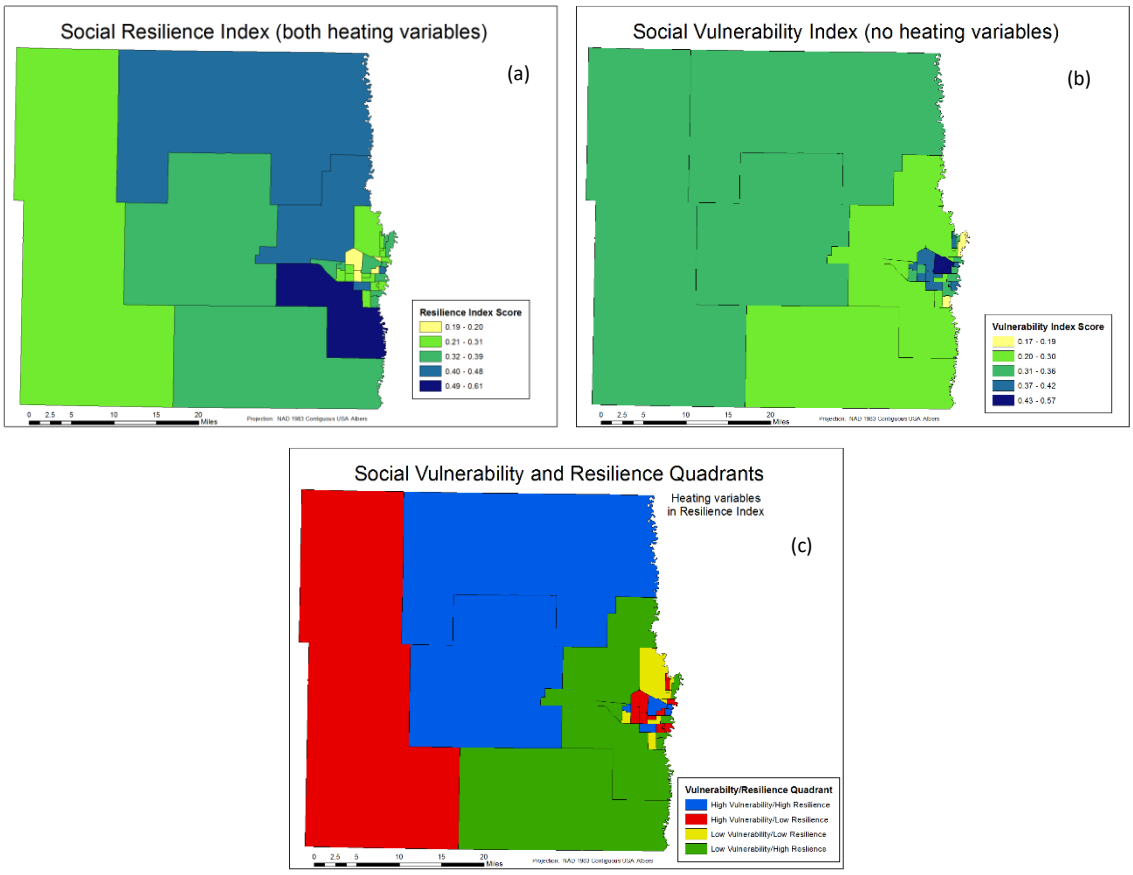

Figure 4.2: Social resilience scores (a), social vulnerability scores (b), and quadrant results (c) for Cass County tracts with both heating variables included in the social resilience index

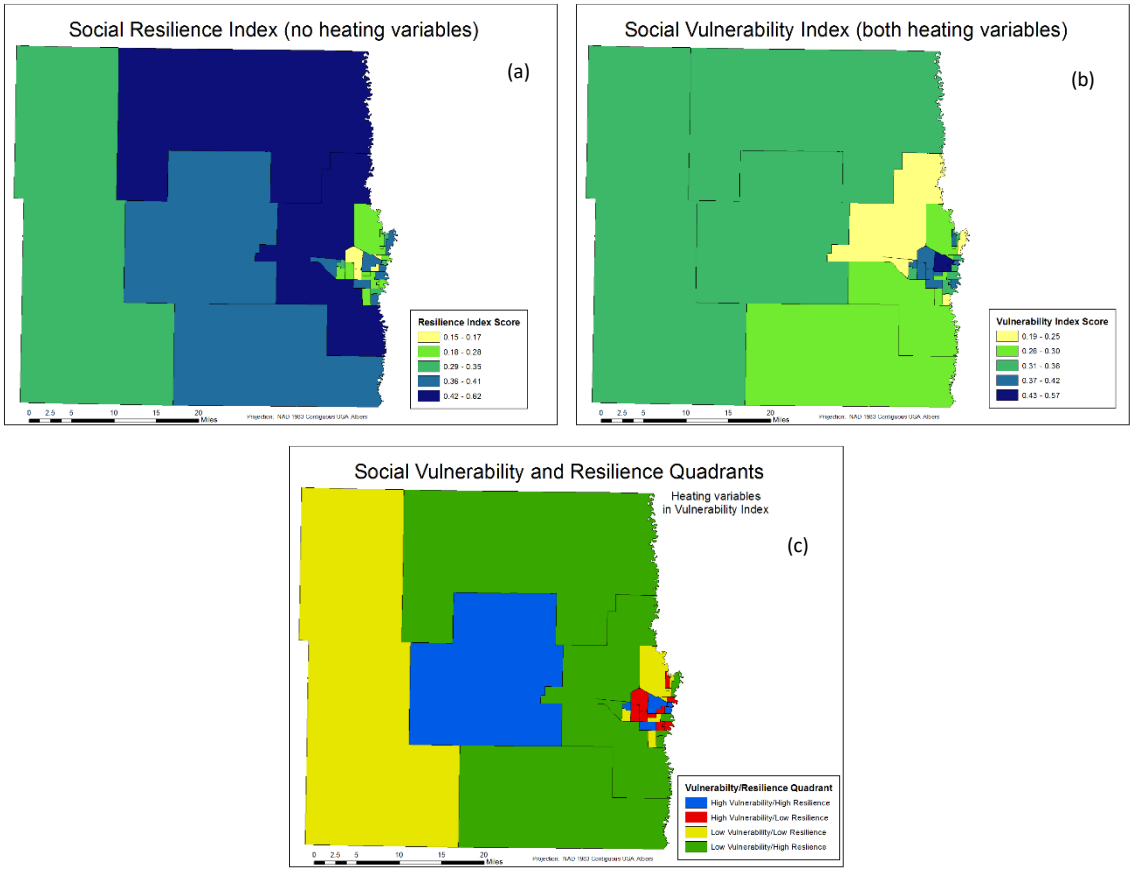

Figure 4.3: Social resilience scores (a), social vulnerability scores (b), and quadrant results (c) for Cass County tracts with both heating variables included in the social vulnerability index

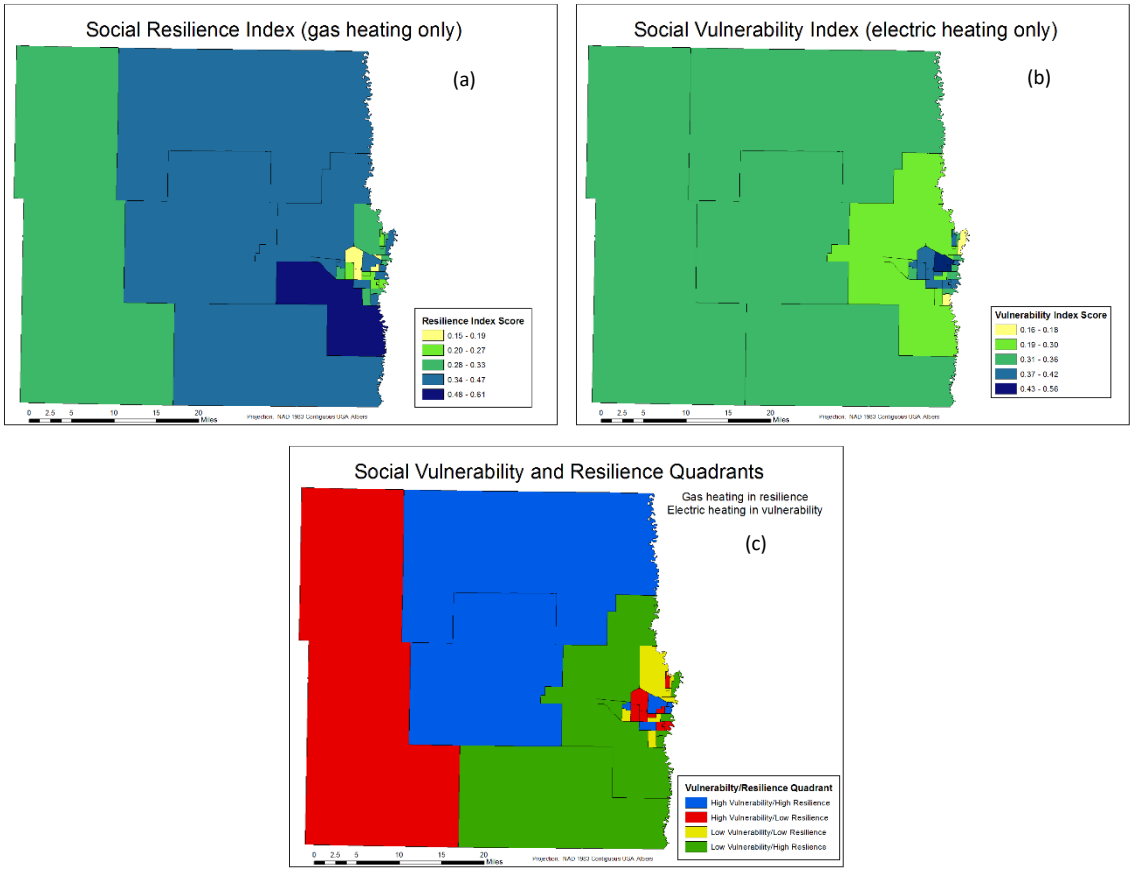

Figure 4.4: Social resilience scores (a), social vulnerability scores (b), and quadrant results (c) for Cass County tracts with gas heating in the social resilience index and electric heating in the social vulnerability index

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary of the Literature

Some of the most commonly studied components of disasters are their risk, people's perceptions, and people's vulnerability or resilience to them. Historically, risk analysis literature largely focused on finding adjustments to help decrease social and economic losses. The social and cultural aspects of risk and risk perception, though, are now being seen more frequently in the research. Through this expansion of the research, experience, knowledge, socioeconomic status, and trust in the community leaders have been shown to impact one's perception. Higher levels of each of these can lead to lower risk perceptions (Short, Jr. 1984; Freudenburg 1993).

Disaster research has become increasingly interdisciplinary, and the main paradigm of the research has also begun to shift. Initially, the main goal was to map where the hazard was most likely to occur and determine the ideal adjustments to be made to mitigate loss. While this is still the case, the need for sociopolitical context has become an important component as well because the community's social structure can contribute to creating a disaster (Kreps 1984; Cutter 2001).

The questions of the field have remained relatively constant but now include recognizing the complexity of the issue and the need for socioeconomic and sociopolitical context (Montz, Cross, and Cutter 2003) and a transition to total risk assessment: the environmental risk, perception, and preparedness (Weichelgartner 2001). Experience and socioeconomic factors are vital components in determining perception and preparation (Kreps 1984; Cutter 2001; Gierlach, Belsher, and Beutler 2010).

Perception has been tied to the concept of place attachment, the connection a person has with their environment, and has been applied to disaster studies in the past in regards to forced relocation (i.e. evacuations) and the impact on environmental perceptions. Many studies have found that people become attached to places even if they are shown to be a high risk area, and multiple factors can influence this attachment. Length of time, though, has been shown to be one of the strongest indicators of attachment (Vorkinn and Riese 2001; Scannell and Gifford 2010; Lewicka 2011; Cresswell 2013).

Scannell and Gifford (2010) argue that place attachment can serve many functions: security and survival, support and self-regulation, and stability. For many rural places such as the Northern Plains, stability may be key as land often stays in the family for generations. In a study of potential hydropower developments in Norway, Vorkinn and Riese (2001) found that stronger place attachment lead to more opposition to the development project and place attachment was a stronger control of this opposition than the sociodemographic variables.

Ritchie, Gill, and Long (2015) developed a concept known as homeplace that may be used as a proxy for place attachment in quantitative analyses. Homeplace divides

length of residence by age to create a variable indicating how much of a person's life is spent in one area. In terms of disasters, this may mean stronger ties to the community and increased knowledge which may then translate into increased resilience.

Explaining disaster preparation behavior and perception may also be explained by two behavior theories: resource mobilization and chaos theory. Resource mobilization, which is usually discussed in reference to social movements, is the securing of control over a needed resource for a collective need, though they are constrained by things such as competition, media attention, and existing systems (McCarthy and Zald 1977; Jenkins 1983). The collective need could be response and recovery from a disaster and the resource as simple as social support (Kaniasty and Norris 1995).

Chaos theory is the idea that conventional cause-and-effect methods cannot predict the outcome of events. Chaotic systems can be disrupted by sudden and irreversible events, such as a disaster (Murphy 1996). While all potential outcomes cannot be predicted, methods such as surveys can be used as a simulation to better understand the system. Examples of chaotic systems include risk perception, crisis (disasters) and decision making (mitigation) used to try to reduce disaster impacts (Gregersen and Sailer 1993). Human behavior and response to stress are highly unpredictable and hard to control, making disaster planning more difficult. Disasters also have the potential to expose previously unknown issues that will now need to be taken into account (Piotrowski 2006).

The decisions made, or lack of decisions, then become a component of the processes that determine social vulnerability. In the latter half of the 1990s, social vulnerability started to become a larger focus of disaster research (Montz, Cross, and

Cutter 2003). Some argue social vulnerability is the key to understanding and reducing risk and can highlight the areas that need the most attention (Birkmann 2006a,2006b; Queste and Lauwe 2006).

The most commonly used social vulnerability indicator is the Social Vulnerability Index (SoVI: Cutter, Boruff, and Shirley 2003; Cutter et al. 2008; Cutter, Burton, and Emrich 2010; Tate 2012, 2013). When calculating social vulnerability indices, socioeconomic variables and services (i.e. police and fire stations) are among the most commonly used (Morrow 1999; Cutter, Boruff, and Shirley 2003; Buckle 2006; Cutter and Emrich 2006; Borden et al. 2007; Cutter et al. 2008; Yoon 2012).

Blizzards can cause millions of dollars in damage each year (Changnon and Changnon 1992; Changnon 2007) and account for nearly 20% of all U.S. hazard fatalities (Borden and Cutter 2008). Because experience with blizzards is highest in the Northern Plains, the residents have the potential to underestimate the risk but still increase their resilience to the storms. This research aimed to determine the exposure, perception, preparedness, and vulnerability/resilience of the Northern Great Plains to blizzards using the following research questions:

1. What is the blizzard exposure in the United States Northern Plains during the snow season (October-April) for the years 1950/51-2010/11?
    a. What is the exposure for seasonal (December-February) versus non-seasonal (October-November and March-April)?
    b. Is there a difference in exposure between early-season blizzards (October-November) and late-season blizzards (March-April)?
    c. Which month(s) exhibit the highest exposure?

d. Has there been a trend in the total number of blizzards? Have there been trends in seasonal storms, early-season storms, and late-season storms?

2. Previous research (Heise 2013) showed South Dakota and North Dakota to have similar risk with more frequent blizzards than the rest of the study area (Figure 1.2). How do people in these states perceive their risk for blizzards? How do they define a blizzard? How do they prepare for the winter season and for blizzards?
    a. Are there differences between various social groups (i.e. urban vs. rural, male vs. female, white vs. non-white, hazard professionals vs. non-professionals) in how risk is perceived and preparation?
    b. Will their perception of risk be lower than the calculated risk?
3. Previous research (Heise 2013) also showed County, North Dakota to have low to average vulnerability at the county level. What is the spatial trend of social vulnerability at the tract level?
    a. How does the inclusion of different variables change the results?

All mapping done in this research used ArcMap 10.3.

Summary of Results and Contributions

Exposure Analysis Summary

Archived daily weather maps from NOAA and the WPC were used to calculate blizzard exposure in the Northern Great Plains for October through April and the years 1950/51 through 2010/11. Any stations missing at least 10% of the data were excluded. To reduce boundary effects, data for stations in the areas immediately surrounding the

study area were also obtained, and the resulting interpolation surface clipped. Higher exposure was defined as having more days under blizzard conditions. To determine if a temporal trend existed, the total number of days were plotted and a trendline fitted.

Data showed that South Dakota was the state with the most blizzard activity with much of the activity concentrated in the western part of the state. Secondary peaks could be found in eastern North Dakota and central South Dakota. March experienced the most blizzards followed by January and then February, and blizzards were more common during the non-seasonal months than during the winter months. It was also found that the late season months (March and April) were more active than the early season months (October and November). With no blizzards recorded in October, this research helps corroborate the argument by Coleman et al. (2015) that the Northern Plains blizzard season begins in November. The 1952/1953 season was the most active season with twelve blizzard days recorded. Ten of those days were during the winter months, 90% of which occurred in February (Smith 1953).

Throughout the study period and the study area, the most activity was found in the paths of the winter midlatitude cyclones and Alberta Clippers. These events were rare between 2000/2001 and 2010/2011, and this could be partially attributed to the increased activity of both El Niño and La Niña events starting in the 1980s (Ross et al. 1998; Changnon 1999; Shabbar and Yu 2009). Two other prominent teleconnections affecting the United States (NAO and PDO) were analyzed along with ENSO to see if a pattern between teleconnection phases and number of blizzard days existed. A preliminary analysis suggested no consistent connection.

The counts for the portions of Montana, Wyoming, and Colorado east of the mountains are generally lower than the rest of the study area, and this could be a result of their position in the rain shadow of the Rocky Mountains. This is not always the case, however, as can be seen with the higher frequencies around the city of Cheyenne. In addition to releasing moisture, the mountains can also increase wind speeds which could then cause blowing snow and a reduction in visibility.

While it was expected to see an overall increase in the number of blizzards during the study period, there was a significant decrease found in the overall frequency, seasonal frequency, and non-seasonal frequencies. These decreasing trends, though not all are significant, correlate well with the McCabe et al. (2001) study suggesting a decrease in the number of Northern Hemispheric midlatitude cyclones as the planet continues to warm. Removing the more active seasons in each category, the decreasing trend remained for each, but they each became less pronounced.

Blizzards are one of the main winter hazards that impact the Northern Plains, and this study focused on a different method for analyzing the risk patterns for these storms. While looking for reported blizzards and atmospheric conditions during the peak seasons, it was discovered that the method used for this study underestimated the number of blizzards. However, the results presented in this risk analysis appear to coincide with results seen in previous studies on blizzard climatology using NOAA county-level data: the Northern Plains are an area of high blizzard activity and the Dakotas the most active. However, it allows the more localized nature of snow events to become apparent by showing sub-county differences in blizzard exposure. This article provides another

possible method for blizzard risk analysis in the event the county level data cannot be obtained. Exposure, however, is just one part of the equation.

Survey Analysis Summary

One of the more commonly used mixed-methods instruments is surveys utilizing both open and closed questions (McLafferty 2010; Bazeley and Jackson 2013) and Internet surveys are becoming more common. Some of the main concerns, however, are the lack of control over the survey respondents, anonymity, and data security (Coomber 1997; McLafferty 2010; Madge 2010). Companies, such as Survey Monkey (surveymonkey.com), are dedicated to helping conduct online surveys for both business and academia, and these companies employ numerous methods to alleviate the concerns of confidentiality and anonymity. For this study, the potential for oversampling of city residents and obtaining a representative sample are the biggest concerns.

To gauge the perceptions and preparation of the residents in the Dakotas, surveys were administered in September 2016 on residents eighteen and older. The initial population sample (100 per state) was randomly chosen by Survey Monkey from their database of previous respondents and these potential respondents were then encouraged to share the survey with their family and friends in the state. A total of 151 surveys were completed and returned. Surveys from existing literature (White 1974; Neal, Perry Jr., and Hawkins 1982; Mileti 1999; Smith 1992; Bourque, Shoaf, and Nguyen 2002; Senkbeil et al. 2014) in combination with preparedness information from the Red Cross (redcross.org/get-help) and NOAA (nws.noaa.gov/om/winter) provided the basis for the survey questions.

Five of the six open-ended questions were analyzed using open coding techniques. Open-coding allows the data to inform the main themes found in the responses. Another coding option is closed-coding in which the researcher begins coding with a set list of themes/idea to find in the data. The personal definition question, because it was compared to the official NWS definition, was analyzed using closed coding techniques. Code frequency tables were generated, and coding results were discussed with colleagues in the Geography, Sociology, and Hotel and Restaurant Administration Departments at Oklahoma State to check reliability and validity. Reliability and validity tests were done by sharing the resulting codebooks and each person coding the responses. Any discrepancies were discussed and a consensus reached on the most appropriate code(s) to attach to the response. To analyze the demographic differences, binary tables of "yes" and "no" were generated so Fisher's Exact Test could be conducted on the coding results. Demographic binaries of interest were male/female, hazard professional/non-professional, city/rural, below Bachelor's/at least a Bachelor's, below/above median income, below/above average homeplace.

The demographics of the survey respondents over-represented some of the populations of the Dakotas according to the 2010 U.S. Census. Most respondents have experienced at least five blizzards in their lifetime. Likely because of this experience, the residents of the Dakotas have a fairly accurate definition of a blizzard. They also appear to be highly prepared. As Adger et al. (2016) suggested, the higher levels of preparation would be expected since the respondents are relatively satisfied with their community leaders as well as having the experience and knowledge of the phenomenon.

Travel conditions and disruption of services were a common theme. Being "snowed in" was frequently mentioned. Most respondents felt more attention should be given to the side streets, frequency of salting and plowing the roads. Monitoring road and weather conditions was also mentioned often when preparing after a watch or warning has been issued, and more so with a blizzard warning. Ranchers and farmers were more concerned about the well-being of their animals than with travel.

Women were more likely than men to include a travel or service disruption component in their blizzard defintion and when detailing their most recent blizzard experience. Rural residents and those with at least a Bachelor's degree included wind as a component more frequently than their counterparts. When discussing experience, hazard professionals and those with below average homeplace were more likely to mention issues with shelter while those with higher levels of formal education described the weather conditions more often compared to their counterparts.

Travel was again more of a concern for women than men when asked to detail preparation activities for blizzard watches and warnings. Men more frequently mentioned ensuring the home and car were ready for the storm. Hazard professionals were also more concerned with road conditions during a blizzard warning than the non-professionals. While education level had no significant impact on preparation during a blizzard watch, advancement to a warning found those with higher levels of education showing more concern for travel conditions than those with less formal education. Income had no significant influence on any of the coded responses analyzed in this study.

The comparisons between urban and rural settings are more complex than this survey suggests. Rural communities may be seen as being more vulnerable because of

their distance from the resources and agencies that provide blizzard response. However, rural communities often have stronger social ties with their neighbors and are more self-reliant, which is what was found in this research. It is these features of rural communities that explain why it was not surprising to find rural residents more dissatisfied with the response of community leaders and that they took more preparative actions during blizzard watches and warnings.

Across all demographic comparisons, road maintenance was a concern. Female respondents were more likely to rate their community leaders as poor in this regard while men rated them as excellent more often. Non-professionals were more satisfied with their community leaders than professionals in all aspects of road maintenance except salting. Residents with less formal education were also more satisfied with their leaders than those with more education on all components of road maintenance except the clearing of side streets. Those with below average homeplace were more satisfied with community leader response than their counterparts, and they were significantly more likely to say that nothing needed improvement. Higher income residents rated their leaders' road maintenance higher than the lower income residents, but the lower income residents were happier with their leaders on clearing the emergency snow routes.

While the results presented in Chapter III may suggest that certain demographic groups do not always follow the trends found in the literature, caution must be taken when applying these results to larger populations. Conducting this survey with those who live in areas where snow is not common could produce much different results due to lack of experience with the hazard. As mentioned earlier, caution should also be taken because a representative sampling cannot be guaranteed with online surveys. The survey

responses presented here do generally corroborate the trends found in existing literature on hazard perception and preparation. However, it adds to the body of work by looking into an underrepresented, yet significant, hazard and region in the United States.

Index Analysis Summary

Data at the tract level was downloaded for Cass County, North Dakota from the 2010 U.S. Decadal Census as well as the 2008-2012 5-year American Community Survey statistics (all obtained using factfinder.census.gov), based on existing literature on social vulnerability and resilience indices, because of the more localized nature of these phenomenon (Cutter, Boruff, and Shirley 2003; Birkmann 2006a,2006b; Buckle 2006; Queste and Lauwe 2006; Cutter et al. 2008; Cutter, Burton, and Emrich 2010; Montz and Tobin 2012; Tate 2012,2013; Cutter, Ash, and Emrich 2014), and this was the smallest geographic area in which all the variables of interest were available.

In addition to the Census data, public services were found using an online Yellow Pages search based on the critical infrastructure described by Parfomak (2005). The main methods for this paper were adapted from Miller, Johnson, and Dabson (2016) by scaling down to the tract level and using only variables from the U.S. Census and American Community Survey. Indicators were normalized by using the min-max rescaling method and then divided into a social resilience index or a social vulnerability index in which the included variables were averaged. The resulting tract scores were averaged, and each tract was labeled as "high" or "low" relative to that average and then assigned to one of four quadrants. Because no consensus has yet been reached on weighting, no weights were used (Cutter, Burton,

and Emrich 2010; Tate 2012, 2013). Because heating source can both increase and decrease vulnerability and resilience, three comparisons were done by moving the two heating variables (gas and electric) between the vulnerability and resilience indices.

Cass County showed near or above average resilience in all three resilience index calculations, especially when neither heating variable was included or included gas heating only. The most vulnerable and least resilience tracts were those in the downtown and city center regions of Fargo and West Fargo where the populations of minorities and those living in poverty are higher. The higher resilience tracts in Cass County have larger families, more formal education, higher median incomes, and more carpooling which gives these areas larger and stronger social networks and better access to resources.

Comparison of the three index quadrants indicates that the method of heating only impacted three of the county's thirty-three Census tracts. Moving one or both of the heating variables into the vulnerability index decreased vulnerability in each of these tracts compared to the average. Two of the tracts are rural and less densely populated, and these residents may be utilizing both methods of heating thus creating a redundant system that reduces vulnerability to power outages. However, increased distances to the nearest city may keep vulnerabilities higher if the power remains out for extended periods of time because of an increased chance of running out of fuel.

The third tract is located near central Fargo on the state border, and it did not change until only the electric heating variable was switched into the vulnerability index. While this tract was classified as "low vulnerability" based on the criteria, it was so close

to the average that it may still be considered a high vulnerability/low resilience location because of its susceptibility to a failure of the electrical grid during a blizzard.

Although the variables used in this analysis can be considered generic indicators of vulnerability and resilience, some can be blizzard-specific. This includes heating (gas is less likely to be interrupted than electric), single mothers and elementary school population (children at home while the mothers have to work), public transit and lack of vehicle access (closing of roads or shut down of public transit may strand residents), rural (increased chance of losing power and becoming stranded), and primary employment (blizzard conditions shutdown production and extraction).

Different results might be found if the data were standardized using another method or aggregated differently. However, the more localized nature of social vulnerability and resilience mentioned frequently in the literature has been reiterated with this study. The county level results from Miller, Johnson, and Dabson (2016) suggest high levels of both vulnerability and resilience in Cass County, but the tract level analyses show that some areas within the county are less vulnerable or less resilient. The use of smaller geographic areas and different aggregation methods can help emergency managers and community leaders see which areas may need more attention and which components of the systems should receive more focus. By doing this, the resources needed to help the community better prepare for and try to prevent the negative impacts of a disaster might be more efficiently mobilized, thus decreasing their vulnerability and increasing resilience.

Contributions and Significance

Other research has suggested that a growing global population and technological advances are driving the rise in disasters worldwide. Extreme events, including blizzards, are also expected to increase as the climate continues to change, and more extreme events could exacerbate certain factors influencing vulnerability (White et al. 2001; Gutowski, Jr. et al. 2008; Lein et al. 2009; Cuevas 2011). With meteorological hazards, warm season extremes are the most commonly researched leaving winter weather hazards understudied, despite their economic and spatial impacts. Blizzard studies are typically focused on risk at the county level because the data is generally archived at this level. However, these storms are generally not experienced uniformly through the county. The results presented in this dissertation show that counties do not have always have uniform exposure as banding is common in snowstorms. By using point data to create an interpolated surface as done in Chapter II, these more localized trends in storm patterns can be found and thus may increase understanding of blizzard risk in addition to providing an alternate method of analysis. By finding a way to analyze the sub-county trends in blizzard exposure, resources and plans for blizzard response can be adapted to increase efficiency. Analysis of monthly, seasonal, and non-seasonal trends can also help community leaders better respond by knowing the time of year in which the storms are most likely to occur.

Most research on blizzards has also been highlighting risk and frequency with little work on perception and vulnerability. It has also been argued that vulnerability, because it is inherently spatial, is one of the bigger questions geographers should address (Cutter, Golledge, and Graf 2002). Vulnerability studies can help increase understanding

of hazards and disasters. The Northern Plains have been shown to have some of the highest levels of social resilience in the country (Cutter, Ash, and Emrich 2014). While resilience is not necessarily the opposite of vulnerability, places that show high resilience do tend to also show lower levels of vulnerability. However, their work was done at the county level, as is much of the work done in this area. The same literature, though, suggests that vulnerability and resilience are more localized phenomenon. Miller, Johnson, and Dabson (2016) analyzed county level data and showed Cass County to be highly resilient and highly vulnerable. However, the tract-level analysis presented in Chapter IV showed that there are pockets of low resilience and high vulnerability within the county (mostly in Fargo). It also shows that locations can be both highly vulnerable and highly resilient (and vice versa) simultaneously, bolstering the argument that resilience and vulnerability are not exclusively opposites. By looking at these smaller geographic levels, those in charge of mitigation and resource allocation can obtain a clearer understanding of where the resources are truly needed and what those resources may be.

Understanding the community's perception of risk and combining it with physical risk has the potential to increase understanding of the phenomenon (Cutter 2001; Buckle 2006; Tobin and Montz 2009). Vulnerability is not static and thus cannot be fully understood through the analysis of static variables alone. By including information such as knowledge, preparation, and perception, emergency managers have access to variables that can improve mitigation plans to better serve their communities. Previous studies into blizzard perceptions have been done (Schwartz 2000), but some bias may have been

introduced by given them a list of options to choose from when defining a blizzard instead of allowing them to freely respond.

Inequalities in the communities may become more apparent by community leaders information on perception, community satisfaction with response, and sub-county level analyses of demographics. This would then allow resources to be steered where they are most needed (de Oliveria Mendes 2009). The research presented in this dissertation shows that county-level analyses can hide more localized trends in exposure, vulnerability, and resilience. Showing these planners and policy makers the localized patterns may help them create more efficient mitigation and response plans that decrease vulnerability and increase resilience.

Future Work

The research done here provides a starting point for expansion. Further work on the exposure analysis would involve a continued expansion of the time period as well as expanding to different regions both within and outside of the United States. More detailed analysis (possibly including regression analysis) may be done to further investigate a possible tie between blizzard activity and teleconnections. Perception, preparedness, and vulnerability studies will likely remain the largest focus of future research. Expansion of the surveys and analysis presented in Chapters III would entail conducting in-person surveys and interviews in these locations to ensure larger sample sizes and more representative samples. The groups that were not represented in the online survey would be targeted, especially populations such as the Native Americans who have long histories of disenfranchisement in the Dakotas.

The inclusion of survey results in indices is planned, and different aggregation methods for index calculation is also expected. Because businesses and policymakers usually prefer to see numbers, quantifying variables such perception and preparedness would allow for their use in an index making it more robust and applicable. Further work is also planned with the methods used in Chapter IV by including some of the non-Census data used in the original work. However, one must be aware that certain information may not be available below the county level due to privacy or data collection limitations.

Comparative studies on blizzard perception and preparedness are also of interest to see how regions like the southeastern or southwestern United States differ in their understanding of a phenomenon that happens much less frequently than in New England or the Northern Plains. It may also be interesting to see if cultural differences, either within the United States or between countries, have a significant influence on these variables and the understanding of the blizzard hazard.

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APPENDICES

APPENDIX 1: IRB APPLICATION AND APPROVALS

Because this research required the use of human subjects with the surveys, approval was needed from Oklahoma State University's Institutional Review Board (IRB). The application was approved in February 2016, and modifications were made and approved in July 2016. The initial application and both approval forms can be found below. The final approved consent form and survey questions used can be found in Appendix 2.

Application for Review of Human Subjects Research Submitted to the Oklahoma State University Institutional Review Board Pursuant to 45 CFR 46	_____ IRB Number FOR OFFICE USE ONLY
Title of Project: Blizzard Risk Perception and Preparedness in the Northern Great Plains	
Is the Project externally funded? ☐Yes ☒No If yes, complete the following: ☐Private ☐State ☐Federal Agency: Grant No: OSU Routing No:	
Type of Review Requested: ☒ Exempt ☐ Expedited ☐ Full Board	
Principal Investigator(s): *I acknowledge that this represents an accurate and complete description of my research. If there are additional PIs, provide information on the additional PIs continuation page form located on the URC website.*	

Keeley S Heise		10 October 2015
Name of Primary PI (typed)	Signature of PI	Date
Geography	Arts and Sciences	
Department	College	
337 Murray Hall	402-650-3966	keeley.heise@okstate.edu
PI's Address	Phone	E-Mail

Required IRB Training Complete: ☒ Yes ☐ No
(Training must be completed before application can be reviewed)

Name of Co-PI (typed)	Signature of Co-PI	Date
Department	College	
Co-PI's Address	Phone	E-Mail

Required IRB Training Complete: ☒ Yes ☐ No
(Training must be completed before application can be reviewed)

Advisor (complete if PI is a student): *I agree to provide the proper surveillance of this project to ensure that the rights and welfare of the human subjects are properly protected.*

Dr. Stephen Stadler		10 October 2015
Advisor's Name (typed)	Signature of Adviser	Date
Geography	Arts and Sciences	
Department	College	
337 Murray Hall	405-744-6250	steve.stadler@okstate.edu
Advisor's Address	Phone	E-Mail

Required IRB Training Complete: ☒ Yes ☐ No
(Training must be completed before application can be reviewed)

NOTE: If sufficient space is not provided below for a complete answer in sufficient detail for the reviewer to fully understand what is being proposed, please use additional pages as necessary.

1. Describe the purpose and the research problem in the proposed study. *Your response in this section will enable the reviewer(s) to determine whether the project meets the criteria of research with human participants and also the extent to which the research may produce new generalizable knowledge that may benefit the participants and/or society.*

The main questions of this research are: what is the risk for blizzards in the states of the Northern Great Plains and how vulnerable are they? How do the residents of these locations perceive their risk? How the residents prepare for a blizzard event? Is there a difference between urban and rural or the general public and professionals?

To obtain this information, a quantitative risk analysis will be done using archived National Weather Service data. The perception and preparedness information will come via survey, and the vulnerability information is via the qualitative survey and US Census data. The vulnerability, perception, and preparedness data will be done by comparison of 2 counties: 1 in North Dakota and 1

in South Dakota, that showed similar vulnerability and risk results in my thesis research based solely on quantitative data.

(a) Describe the subjects of this study:

1) Describe the sampling population: The sampling population is any resident of either Pennington County, South Dakota or Cass County, North Dakota that are aged 18 and over. The potential subjects will be selected via an online survey site, so those residents in these counties that have previous participation in surveys for that company will be the main source for potential subjects. As part of the introduction to the research survey, those who are sent the link will be encouraged to share it with others aged 18 and over in their community who they feel can provide valuable information to the research. The proposed survey site is Survey Monkey. They use SSL encryption to protect the information as is it being sent across the Internet, and they provide the option to choose to not save certain information (i.e. IP addresses, contact emails) with the responses so the report sent to the PI would be responses only with no personally identifying information attached. Norton and TRUSTe privacy software are also used by Survey Monkey to protect and validate the data and privacy of the respondents.
2) Describe the subject selection methodology (i.e. random, snowball, etc.): The selection methodology will be both random and snowballing. The initial subjects will be chosen at random by the company from their list of previous survey participants. Those respondents will then be encouraged to share the survey link to others in their local community within the county borders.
3) Describe the procedures to be used to recruit subjects. Include copies of scripts, flyers, advertisements, posters, and letters to be used. **If recruitment procedures will require access to OSU System email addresses you will need to include Appendix A of this application**:[7] The subjects will be recruited through the online survey company using their database of previous survey respondents in the selected counties. Email will be the main recruitment method.
4) How many subjects are expected to participate? 500 per county
5) What is the expected duration of participation for each segment of the sampling population? If there is more than one session, please specify the duration of each session: 15-20 minutes
6) Describe the calendar time frame for gathering the data using human subjects: March-June 2016
7) Describe any follow-up procedures planned: none currently planned after June 2016. If possible, the survey company will be asked to send out reminder emails periodically. Final aggregated results may be sent to the county emergency managers.

(b) Are any of the subjects under 18 years of age? ☐ Yes ☒ No

If Yes, have you completed the training for minors participating in OSU-related activities and programs? ☐ Yes ☐ No Date of completion _____ If no, the training must be completed before IRB approval can be given. Click here to access the training. Click here to view policy 1-0135 "Minors Participating in OSU-Related Activities and Programs".

If using minors in research, you must comply with special federal regulations. Please refer to the IRB Guide.

2. Provide a detailed description of any methods, procedures, interventions, or manipulations of human subjects or their environment and/or a detailed description of any existing datasets to be accessed for information. Please indicate the physical location where the research will take place

(if applicable). Include copies of any questionnaires, tests, or other written instruments, instructions, scripts, etc., to be used.

Existing databases to be accessed for information include the 2010 US Census for a vulnerability analysis at the tract level. The risk analysis will obtain data from archived NOAA (National Oceanic and Atmospheric Administration) daily weather maps. Both of these can be accessed online, and this will be done while the surveys are being distributed and completed by the participants via the online survey site. The risk perception and preparedness information will be obtained via an online survey. The questions on the survey will ask for basic demographic information (age, gender, occupation, annual income, urban or rural residence, race/ethnicity, number of residents in household, residence tenure, rent or own, language) as well as specific questions relation to their perception of risk and preparedness: experience with blizzards, distance to nearest services (police, fire, library/community center, medical clinics, hospitals), how they heat their home, number of vehicles, food and water storage in home and car, snow supplies in car, backup communication or heat source, recurrence, personal definitions of the concepts, and expected role of the government.

The surveys will be submitted to the online survey site for them to disperse to potential subjects they chose through an existing database of people who have completed surveys for them in the past. The pool of possible subjects will be residents of Pennington County, South Dakota and Cass County, North Dakota. Pennington County was chosen for its relative proximity to some of the South Dakota reservations. Both counties also have just one major urban area within the county. All parts of the process that deal with recruitment, dispersal, and collection of survey responses will be handled by the survey site and then reported to the PI. The survey responses will be collected by the PI from the site and downloaded into an Excel spreadsheet for analysis. The surveys will be anonymous as I will not have any identifying information within the survey nor attached to the survey responses.

3. Please list by position any additional personnel (undergraduate assistants, graduate research assistants, members of the community) who will be involved in the recruitment or consent process or data collection and/or analysis. Names are not necessary.
   Include a description of the training in the protection of human subjects in research that these individuals will be required to complete.
   No other actual personnel to be used outside of the independent online survey site

5. Will the subjects encounter the possibility of stress or psychological, social, physical, or legal risks that are greater than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests? ☐Yes ☒No
   If Yes, please justify your position:

6. Will medical clearance be necessary for subjects to participate because of tissue or blood sampling, administration of substances such as food or drugs, or physical exercise conditioning?
   ☐Yes ☒No
   If Yes, please explain how the clearance will be obtained:

7. Will the subjects be deceived or misled in any way? ☐Yes ☒No
   If Yes, please explain:

8. Will information be requested that subjects might consider personal or sensitive? ☒Yes ☐ No
   If Yes, please explain: Race/ethnicity, income range, occupation, age

9. Will the subjects be presented with materials that might be considered offensive, threatening, or degrading? ☐Yes ☒No
If Yes, please explain, including measures planned for intervention if problems occur.

10. Will any inducements be offered to the subjects for their participation? ☐Yes ☒No
If Yes, please explain:
NOTE: If extra course credit is offered, describe the alternative means those students who do not wish to participate in the research project may employ to obtain the course credit.

11. Describe the process to be used to obtain the consent/assent/parental permission of all subjects (as appropriate). Who will seek the consent/assent/permission? Describe the steps taken to minimize coercion or undue influence, and the method(s) to be used to document consent/assent/permission.
Please submit copies of all consent documents with your application
Consent will be obtained by the survey company. The email sent to potential respondents, as well as the first page of the survey, will contain an explanation of the research and research questions being addressed by the survey. Consent for participation will be given by the respondent clicking on the link and clicking okay to proceed to the questions. The will also have the option to skip and questions they do not feel comfortable answering.

12. Are you requesting a waiver of documentation of consent (no signature on consent/assent forms)? If you are conducting a survey, online or in paper form, check yes if respondents will remain anonymous.
☒Yes ☐No
If yes, provide a justification for waiving documentation based on one of the two criteria allowing the waiver.
The principle risk is a confidentiality breach, and a written consent form would be the only way to connect the respondent to the research. There is also minimal risk to the participants outside the normal daily risk they would encounter. As this survey is being conducted entirely online, respondents will be completely anonymous.

13. Do you wish to waive some of the elements of consent/assent/ parental permission or the entire consent/assent/parent permission process?
☐Yes ☒No
If yes, provide a justification for the waiver that addresses all criteria that must be met for the waiver to be approved.

14. Will the data be a part of a record that can be identified or linked to particular subjects? ☐Yes ☒No
If Yes, please explain:

15. Describe the steps you will take to protect the confidentiality of the subjects and how you will advise subjects of these protections during the consent process. Include information on data storage and access. If data will not be reported in the aggregate, please explain how the data will be reported.
The survey will be administered through an online survey system and no specific identifying information will be requested via the survey questions, allowing the survey to remain anonymous. Survey response data will be recorded in a spreadsheet maintained on my personal computer, which is password protected. Each survey will be identified by an assigned survey record number. Upon completion of data collection, the data will be aggregated and reported as statistics. No identifying information will be kept with the survey results, as none will be recorded during the survey process.

16. Will a subject's participation in a specific experiment or study be made a part of any record available to his or her supervisor, teacher, or employer? ☐Yes ☒No
If Yes, please explain:

17. Will the consent form and other documents (i.e. recruitment materials, surveys, etc.) be translated into non-English versions? ☐Yes ☒No
If yes, please attach the Translator Declaration Form.

18. Describe the benefits that might accrue to either the subjects or society. *Note that 45 CFR 46, Section 46.111(a)(2) requires that the risks to subjects be reasonable in relation to the anticipated benefits. The investigator should specifically state the importance of the knowledge that reasonably may be expected to result from the research*

Potential benefits for the society include improved preparedness and mitigation plans by those in charge of the disaster policies. By providing final results and information to the county emergency managers in the study area, they can gain a better understanding of the perception and needs of those they are serving which can, in turn, help them to update and improve plans regarding blizzards and other winter natural hazards that impact their citizens. For the general public, participating in this survey will allow them to take stock of their plans and preparedness for severe winter weather, and it may allow them to find weaknesses in their own plans that they can work on if they desire.

INITIAL APPROVAL

Oklahoma State University Institutional Review Board

Date:	Monday, February 22, 2016
IRB Application No	AS15115
Proposal Title:	Blizzard Risk Perception and Preparedness in the Northern Great Plains
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 2/21/2019

Principal Investigator(s):

Keeley S Heise
337 Murray
Stillwater, OK 74078

Steven Stadler
337 Murray
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1.Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval. Protocol modifications requiring approval may include changes to the title, PI advisor, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms
2.Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3.Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of the research; and
4.Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Dawnett Watkins 219 Scott Hall (phone: 405-744-5700, dawnett.watkins@okstate.edu).

Sincerely,

Hugh Crethar, Chair
Institutional Review Board

Please read the following material that explains this research study. Accepting the invitation to participate in the study will indicate that you have been informed about the study and that you want to participate. We want you to understand what you are being asked to do and what risks and benefits—if any—are associated with the study. This should help you decide whether or not you want to participate in the study.

Introduction and purpose
You are being invited to take part in a research project conducted by Keeley Heise of Oklahoma State University as part of her doctoral dissertation research. She can be reached by email at keeley.heise@okstate.edu.

This study is designed to assess the perception of risk and preparedness levels for blizzards and other snow storms in the Northern Plains states.

Why is this study being done?
Blizzards and severe snowstorms are among the most damaging weather events in the United States. However, comparatively little research has been done on these weather events, especially in the Plains and Midwest. Another aspect not seen frequently in the research is the perception of the residents and how they prepare for the annual winter snowstorms in the region. This study looks to address these issues with the aim of improving mitigation plans in the Northern Plains by providing those in charge with an overview of their community's perception and preparedness levels.

You have been invited to participate because you live in an area known to experience blizzards and other types of snowstorms on a fairly regular basis. As someone who grew up in northeast Nebraska, Keeley has always been interested in how people think about winter weather and she is eager to see your responses and very hopeful that it can improve responses in your community.

What are the study procedures? What will I be asked to do?
If you agree to take part in this study, you will be asked to answer questions from a web-based survey. Your answers to the survey will be collected anonymously and stored on a password protected computer. The survey questions are grouped into three sections: 1) perception of risk; 2) preparedness level; 3) basic demographics.

The survey is designed to take 45 to 60 minutes to complete. You are also encouraged to pass this along to family, friends, neighbors, or coworkers in your county that you feel would be willing and able to complete this survey or could provide valuable information.

What other options are there?
The study has been developed as a web-based survey. Upon request, we can provide you with a .pdf, docx or hardcopy version of the survey, but we ask that responses be submitted through the web to maintain confidentiality. If you decide you do not wish to participate or do not wish to complete the survey, you can stop and close your browser window at any time.

What are the risks or inconveniences of the study?
There are no foreseeable risks to taking part in this study.

What are the benefits of the study?
Aggregated results may be sent to the emergency managers in your area in the hopes that it will help them improve their planning and mitigation policies in regards to blizzards and snowstorms so as to reduce the financial and social loss.

Will I receive payment for participation? Are there costs to participate?
There are no costs and you will not be paid to be in this study.

How will my personal information be protected?
The survey will be anonymous. No names, email addresses or IP addresses are collected as part of the survey. The data will be stored on a password protected computer accessible only by the principal investigator. We will do our best to protect the confidentiality of the information we gather from you but we cannot guarantee 100% confidentiality. Your confidentiality will be maintained to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties.

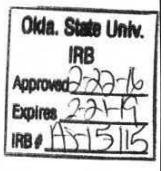
You should also know that the Oklahoma State University Institutional Review Board (IRB) and Research Compliance Services may inspect study records as part of its auditing program, but these reviews will only focus on the researcher and not on your responses or involvement. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

Can I stop being in the study and what are my rights?
You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you can drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate. You do not have to answer any question that you do not want to answer.

Whom do I contact if I have questions about the study?
Take as long as you like before you make a decision. I will be happy to answer any question you have about this study. If you have further questions about this study or if you have a research-related problem, you may contact the principal investigator, Keeley Heise at keeley.heise@okstate.edu. If you have any questions concerning your rights as a research participant, you may contact the Oklahoma State University Institutional Review Board (IRB) at irb@okstate.edu.

Can I take the survey on my portable device?
While the survey was designed to be taken from any device, some of the Likert-scale questions will be easier to complete on laptop, notebook or desktop computers with larger screens.

I'd like to participate in this study, what do I do now?
You can participate in this study by clicking the Next button and taking the web-based survey.



MODIFICATION APPROVAL

Oklahoma State University Institutional Review Board

Date:	Wednesday, July 20, 2016	Protocol Expires:	2/21/2019
IRB Application No:	AS15115		
Proposal Title:	Blizzard Risk Perception and Preparedness in the Northern Great Plains		
Reviewed and Processed as:	Exempt **Modification**		

Status Recommended by Reviewer(s) **Approved**

Principal Investigator(s):

Keeley S Heise
337 Murray
Stillwater, OK 74078

Steven Stadler
337 Murray
Stillwater, OK 74078

The requested modification to this IRB protocol has been approved. Please note that the original expiration date of the protocol has not changed. The IRB office MUST be notified in writing when a project is complete. All approved projects are subject to monitoring by the IRB.

The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

The reviewer(s) had these comments:

Mod to recruit from all of North and South Dakota rather than specific counties and to remove some of the survey questions.

Signature :

Hugh Crethar, Chair, Institutional Review Board

Wednesday, July 20, 2016
Date

Please read the following material that explains this research study. Accepting the invitation to participate in the study will indicate that you have been informed about the study and that you want to participate. We want you to understand what you are being asked to do and what risks and benefits—if any—are associated with the study. This should help you decide whether or not you want to participate in the study.

Introduction and purpose
You are being invited to take part in a research project conducted by Keeley Heise of Oklahoma State University as part of her doctoral dissertation research. She can be reached by email at keeley.heise@okstate.edu.

This study is designed to assess the perception of risk and preparedness levels for blizzards and other snow storms in the Northern Plains states.

Why is this study being done?
Blizzards and severe snowstorms are among the most damaging weather events in the United States. However, comparatively little research has been done on these weather events, especially in the Plains and Midwest. Another aspect not seen frequently in the research is the perception of the residents and how they prepare for the annual winter snowstorms in the region. This study looks to address these issues with the aim of improving mitigation plans in the Northern Plains by providing those in charge with an overview of their community's perception and preparedness levels.

You have been invited to participate because you live in an area known to experience blizzards and other types of snowstorms on a fairly regular basis. As someone who grew up in northeast Nebraska, Keeley has always been interested in how people think about winter weather and she is eager to see your responses and very hopeful that it can improve responses in your community.

What are the study procedures? What will I be asked to do?
If you agree to take part in this study, you will be asked to answer questions from a web-based survey. Your answers to the survey will be collected anonymously and stored on a password protected computer. The survey questions are grouped into three sections: 1) perception; 2) preparedness; 3) basic demographics.

The survey is designed to take 15-20 minutes to complete with 35 questions. You are also encouraged to pass this along to family, friends, neighbors, or coworkers in your state that you feel would be willing and able to complete this survey or could provide valuable information, especially those in Pennington County, South Dakota and Cass County, North Dakota.

What other options are there?
The study has been developed as a web-based survey. Upon request, we can provide you with a .pdf, docx or hardcopy version of the survey, but we ask that responses be submitted through the web to maintain confidentiality. If you decide you do not wish to participate or do not wish to complete the survey, you can stop and close your browser window at any time.

What are the risks or inconveniences of the study?
There are no foreseeable risks to taking part in this study.

What are the benefits of the study?
Aggregated results may be sent to the emergency managers in your area in the hopes that it will help them improve their planning and mitigation policies in regards to blizzards and snowstorms so as to reduce the financial and social loss.

Will I receive payment for participation? Are there costs to participate?
There are no costs and you will not be paid to be in this study.

How will my personal information be protected?
The survey will be anonymous. No names, email addresses or IP addresses are collected as part of the survey. The data will be stored on a password protected computer accessible only by the principal investigator. We will do our best to protect the confidentiality of the information we gather from you but we cannot guarantee 100% confidentiality. Your confidentiality will be maintained to the degree permitted by the technology used. Specifically, no guarantees can be made regarding the interception of data sent via the Internet by any third parties.

You should also know that the Oklahoma State University Institutional Review Board (IRB) and Research Compliance Services may inspect study records as part of its auditing program, but these reviews will only focus on the researcher and not on your responses or involvement. The IRB is a group of people who review research studies to

protect the rights and welfare of research participants.

Can I stop being in the study and what are my rights?
You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you can drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate. You do not have to answer any question that you do not want to answer.

Whom do I contact if I have questions about the study?
Take as long as you like before you make a decision. I will be happy to answer any question you have about this study. If you have further questions about this study or if you have a research-related problem, you may contact the principal investigator, Keeley Heise at keeley.heise@okstate.edu. If you have any questions concerning your rights as a research participant, you may contact the Oklahoma State University Institutional Review Board (IRB) at irb@okstate.edu.

Can I take the survey on my portable device?
While the survey was designed to be taken from any device, some of the Likert-scale questions will be easier to complete on laptop, notebook or desktop computers with larger screens.

I'd like to participate in this study, what do I do now?
You can participate in this study by clicking the Next button and taking the web-based survey.

APPENDIX 2: SURVEY CONSENT FORM

Please read the following material that explains this research study. Accepting the invitation to participate in the study will indicate that you have been informed about the study and that you want to participate. We want you to understand what you are being asked to do and what risks and benefits—if any—are associated with the study. This should help you decide whether or not you want to participate in the study.

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What are the risks or inconveniences of the study?

There are no foreseeable risks to taking part in this study.

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VITA

Keeley S. Heise

Candidate for the Degree of

Doctor of Philosophy

Thesis: BLIZZARD RISK, PERCEPTION, AND PREPAREDNESS IN THE NORTHERN GREAT PLAINS

Major Field: Geography

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Geography at Oklahoma State University, Stillwater, Oklahoma in May, 2017.

Completed the requirements for the Master of Science in Geography at Oklahoma State University, Stillwater, Oklahoma in 2013.

Completed the requirements for the Bachelor of Science in Meteorology/Climatology at University of Nebraska-Lincoln, Lincoln, Nebraska in 2006.

Experience: Lab TA Introduction to Physical Geography
Lecture instructor Introduction to Physical Geography
Online lecture instructor Introduction to Meteorology

Professional Memberships: National Society of Collegiate Scholars
Gamma Theta Upsilon
Golden Key
American Meteorological Society
American Association of Geographers