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SC Floods Project Summaries

Collected abstracts detailing projects funded by the Office of the Vice President for Research through the 2015 SC Floods Research Initiative.

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UNIVERSITY OF SOUTH CAROLINA

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As floodwaters crested last October, we began to see that South Carolina would be forever changed by a natural disaster that ravaged rural, urban and suburban communities, ruined crops just as they were nearing readiness for harvest, destroyed businesses, took lives and compromised vital infrastructure systems that we rely on every day. It seems that no one was left untouched by the devastation. Remarkably, rather than descend into despair, South Carolinians banded together in the days during and after the flood, supporting neigbors, friends and family through efforts that continue today.

As I watched the news from my home, and experienced the flood's effect on my own neighborhood community, my urge to help grew, and took shape. I reached out to university colleagues, and together we organized an unprecedented effort to fund USC faculty flood research projects that would contribute to our understanding of what happened and to the future well-being of our community.

Within hours of USC's return to normal operations, my team launched this effort, issuing a request for proposals throughout the USC System. Within a week's time, dozens of USC faculty from a wide variety of academic disciplines submitted research proposals. Another week later, our faculty review committee awarded funding to 34 research projects in subject areas from communications to biology, from disaster experiences to infrastructure impacts. This rapid response allowed our faculty to begin gathering information within two weeks of the catastrophic floods, enabling them to capture even the most perishable data.

The extended abstracts in this booklet provide a view into the outstanding work USC's researchers have completed in their months-long efforts to better understand and mitigate the risks to our community. It is our collective goal that, the next time a natural disaster threatens the Palmetto State, we will be better prepared to face and overcome the challenges it brings with it.

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The Office of the Vice President for Research

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&

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for their contributions as co-chairs of the SC Floods Conference and for their work in organizing SC Floods researchers as the initiative was in its earliest stages.

Keynote Speaker

Kevin A. Shwedo

Executive Director

SC Department of Motor Vehicles (SC DMV)

On October 19, 2015**,** Governor Nikki Haley called on SC Department of Motor Vehicles (SC DMV) Executive Director Kevin A. Shwedo to take the lead as the state coordinator for flood recovery, a position created by executive order specifically to manage the 2015 statewide flood event. The executive order tasked Shwedo with recommending short- and long-term recovery efforts in areas including community planning, economic recovery, housing recovery and more. The role kept Shwedo busy for months, traveling to affected areas around the state to assess needs, attending town hall meetings to talk with locals impacted by flooding and performing countless other coordination duties.

Of her appointment of Shwedo to this role, Governor Haley said, **"When it comes to response, when it comes to recovery, when it comes to logistics and when it comes to people, there is no one better who I can think of to be my point person than Colonel Shwedo."**

After his responsibilities as the state coordinator for flood recovery were finished, Shwedo returned to his role as the Executive Director of the SC DMV. In this capacity, he oversees the functions and responsibilities of the entire agency.

Prior to his January 2011 appointment as head of the SC DMV, Shwedo was the Deputy Commanding Officer of the United States Army Training Center at Fort Jackson. He retired from the United States Army on February 1, 2011, with 32 years of service. During his military career, Shwedo served in various leadership and developmental positions within the Army. His awards include the Distinguished Service Medal, two awards of the Legion of Merit, Defense Meritorious Service Medal and eight awards of the Meritorious Service Medal.

Biology

Communications

Disaster Experiences

Economic Impacts

Health

Impact Assessment

Infrastructure

Recovery & Resilience

River Systems

Effects of the October 2015 Flood on a High Salinity Estuary: Responses and Recovery of Habitat and Animal Populations

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Introduction

The October 2015 flood event resulted in a massive influx of river discharge to the north coast estuaries. The influx of low salinity water into the usually salty North Inlet estuary (NIe) was unprecedented in the >35 years that USC researchers have been studying the ecology of its salt marsh and tidal creeks. This presented an opportunity to observe and interpret responses of aquatic animal populations and assess the resiliency of the ecosystem to such a large natural perturbation. Frequent collections of nekton (motile fishes, shrimps, and crabs), zooplankton (microscopic permanent residents and larvae of larger invertebrates and fishes), and oyster reef fishes provided an understanding of the impacts of the influx of low salinity water on the diversity, abundance, and reproductive success of about 50 major groups of estuarine animals.

Methodology

Collections were made at a location in the core of the ocean-dominated NIe and at the interface of this high salinity system and the river-dominated Winyah Bay estuary (WBe). Both locations were sampled monthly during winter and biweekly starting in March. To sample the small mesozooplankton (0.5-3 mm), we used a 153 micron ring net at the surface. The large mesozooplankton (4-25 mm) was collected with a 365 micron net attached to an epibenthic sled. Larger swimming forms (nekton, 20-1000 mm) were sampled with an otter trawl. All nets were towed from a small boat in shallow salt marsh creeks, around the morning low tide and afternoon high tide for the zooplankton, and early in the rising tide for the nekton. Resident oyster reef fish were sampled with artificial nesting substrates. Water quality (including salinity) was measured continuously.

Results

Following the October 2015 flood, freshwater discharges from the rivers significantly diluted the salty waters that normally prevail in Winyah Bay, the largest estuary in South Carolina. Resulting low salinity waters spilled into the adjacent NIe where tidal exchanges with the ocean usually maintain high salinity. The influx of riverine water was more rapid and prolonged than at any time in at least 35 years. Influence of the spill-over into NIe was greatest around low tides; rising tides moved low salinity waters back toward WBe. Very large swings in salinity between tides continued until a series of unusually high tides reestablished high salinity in NIe in late October. However, additional rains typical of El Niño winters in South Carolina resulted in rapid runoffs from the still flood-soaked watershed and resulted in at least five extended periods of high river discharge and lowered salinity in NIe through March. Diminishing river discharges into WBe and increasing ocean influence reestablished high salinity conditions in NIe in April.

Immediately after the flood, very large catches of shrimps, crabs, and fishes displaced from WBe occurred in NIe. Species richness reached record high levels. Small mesozooplankton (mainly copepod) densities were greatly reduced, whereas large mesozooplankton densities increased greatly with the introduction of low salinity amphipods and mysids. As the salinity pattern changed during winter, various species indicative of certain salinity ranges appeared and disappeared in NIe. At the lowest salinity in January, species of freshwater catfish, herrings, and other fishes and crustaceans were recorded in NIe for the first time. Pulses of fish and shrimp larvae arriving from the ocean, locally produced barnacle and other larvae, and copepods during the winter and early spring were as expected, but peak abundances of some species were especially high. By July, water quality (including salinity) and fauna composition and abundances in NIe were typical. Although some minor changes attributed to the flood remain, no indications of major structural and functional changes have been identified.

Summary and Conclusions

Flood-driven, river discharges into Winyah Bay estuary caused record reductions in salinity in the adjacent North Inlet estuary during October. Additional discharges during the winter caused periodic salinity reductions through March. These events resulted in the introduction of fish, shrimp, and zooplankton species that normally live in the rivers, but their occurrences were short-lived. Deviations from long-term patterns of abundances of some species were observed and some impacts persisted into the following summer; however, the historic perturbation did not fundamentally alter the structure of animal communities in the North Inlet estuary. The study expanded our understanding of spatial and temporal dynamics of species of both ecological and economic importance, and it demonstrated the resilience of estuarine ecosystems to major natural disturbances.

Flooding Effects on a Newly Described and Very Rare Plant Species, *Stachys caroliniana*

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Shelby Moody, School of the Earth, Ocean, and Environment

Introduction

Stachys is one of the largest genera in the mint family (Lamiaceae), with 12 species in the southeastern United States. One species, *Stachys caroliniana*, was first discovered from a single location at the Santee Coastal Reserve in Charleston, SC in 1977. That population has since vanished. In 1990, another population was found at the Tom Yawkey Wildlife Center, SC. This species is currently known from no other populations.

During the October floods, the population was covered by at least 0.75m of water for days. Our study examined the impact of flooding on the persistence of the population. While *S. caroliniana* lives in moist soils, the effect of complete inundation for a longer time period is unknown. Knowledge of this aspect of the plant's biology is critical to the management of this potentially endangered species.

Methodology

We did an initial population survey in December 2015 following the October flood. The population was divided into six subpopulations (A-F) for data collection. One plant is defined as a single stem that is rooted in the ground. We flagged and counted all remaining stems. Each stem was categorized as: Living (currently non-reproductive), Budding, Flowering, Seeding, or Dead. Stemlets are stems that are coming off of the main stem. These were counted for each stem. Plant density and areal percent cover of the sky by trees were calculated for each subpopulation. Surveys were repeated in May and July 2016. Beginning with the May 2016 counts, half of the subpopulations were weeded to remove competition from other plants. This management approach will be compared to subpopulations that are not weeded to assess which strategy is most beneficial to the species.

Results

The flood did not kill large numbers of plants. The initial stem count in December 2015 included a total of 567 individual plants. Of these, 6% were dead. The percent dead stems in each sub-plot decreased with overall areal coverage of the sub-plot by trees, hence decreased with increasing shade.

The stem count nearly doubled in May, with a total of 1,074 stems, and no dead stems were present. This result confirms that the dead stems counted in December were from 2015, and not earlier. Plants were starting to flower.

In July the overall stem count decreased to 1,069. This decrease was caused by two of the three sub-plots that were not weeded, C and D; stem numbers in the other four sub-plots increased. Nonetheless, there was no significant difference in change of stem number between May and July due to weeding treatment. The change in stem number showed an increasing trend with increasing amount of shade, although the relationship was not significant. However, proportion of stems with seeds was significantly correlated with change in stem numbers in a sub-plot, suggesting that plant phenology drove the change in stem numbers.

Summary and Conclusions

Inundation to a depth of over 0.75m for several days due to the October floods appears not to have harmed the only known population of *S. caroliniana*. The population recovered well in spring 2016. Demographic data on this population will continue to be collected through spring 2017. An analysis of the resulting life history matrix for the subpopulations will help determine whether inundation is instead a potential management technique.

Flood Mediated Removal of Introduced Black Basses From Select South Carolina Streams

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Introduction

Introduced species pose serious threats to endemic fishes, especially for endemics with narrow distributions. Bartram's bass, an undescribed black bass endemic to the Savannah River, is threatened by extinction from introduced Alabama bass. Alabama bass are pervasive throughout the Savannah River, but appear less common in areas of high discharge. The recent flood event in South Carolina offered an opportunity to test the idea that invasive species are differentially (adversely) impacted by high flow events. We utilized previously sampled individuals from streams containing various levels of Alabama bass and hybrids to estimate the composition of black basses in three South Carolina streams as a baseline to compare current species composition after the flood event of October 3-4.

Methodology

We designed four genetic assays utilizing hydrolysis probes (Greenwold unpublished) and allele-specific polymerase chain reaction with confronting two-pair primers (PCR CTPP) to genetically assay black basses collected from three stream systems in the Piedmont of South Carolina, and developed probes targeting the mtDNA genome to facilitate more rapid assays (relative to direct DNA sequencing). We used these genotypic categories (i.e., Bartram's, Alabama bass, hybrid) to compare pre- and post-flood composition using a series of Fisher's exact tests both individually and in a pooled data set. Fish are being captured by hook-and-line and/or electrofishing in a manner consistent (seasonally and methodologically) with that used to collect pre-flood individuals so as to not introduce sampling bias. Small fin biopsies are being removed for genetic analysis and photographs taken before releasing individuals unharmed.

Results

To date, we have developed assays for three bi-allelic nuclear loci (actin, calmodulin, ITS) for which species diagnostic allelic variation exists. We have also designed a CTTP assay that differentiates the mitochondrial genome of invasive Alabama bass from Bartram's bass.

We have used these assays to determine the composition of classes of black bass (Alabama bass, Bartram's bass, hybrids) in three South Carolina streams (Little River, Twelvemile Creek, Chauga River) prior to the flood event of October 2015. All three streams harbor hybrid basses, the result of hybridization events involving introduced Alabama bass and native Bartram's bass. However, there is an appreciable difference in the frequency of invasive spotted bass and hybrid individuals (IBB) among these three streams. Importantly, individuals sampled in the high-gradient Chauga River were almost wholly comprised of "pure" Bartram's bass (95%), whereas the lower gradient Little River and Twelvemile Creek populations were biased towards a higher frequency of IBB individuals (30-75%).

Because we wished to sample these same locations post-flood seasonally and methodologically, our sampling has been concentrated in the late summer months, principally August and September. However, rain discharge has thwarted attempts to sample these locations either by electrofishing or hook-and-line during most of August, and we are currently sampling these regions during early to mid-September. Once collected, we will assay all individuals and assign each to their respective category (e.g., IBB versus Bartram's bass) and compare frequencies to those individuals collected before the flood event of 2015. These studies are ongoing.

Summary and Conclusions

To date, we have developed and implemented genetic assays to differentiate native Bartram's bass from the invasive spotted bass and their hybrids. These assays were subsequently used to assay individuals from three Piedmont streams and categorize these individuals as Alabama bass, Bartram's bass and hybrid. Our pre-flood data suggests that spotted bass and hybrid individuals are rare in high gradient areas relative to lower gradient regions in the Piedmont of South Carolina. Our surveys of animals post-flood are ongoing as sampling during the late summer has been difficult, but we are confident that comparable genetic data for these three regions will be gathered prior to October 7.

Conservation Biogeography of Fishes: Community Dynamics and Shifts in Response to a 1,000-Year Rainfall Event

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Introduction

Within a riverscape, fluvial dynamics cause shifting habitat mosaics at the spatial scale of the floodplain. Waterbodies are created by fluvial processes through lateral and vertical erosion and subsequent channel migration/abandonment. These waterbodies include side-arms, streams/creeks, cut-off channels, oxbow lakes, floodplain ponds, and marshes. At this scale, diversity of biotically significant habitat conditions results from the distance from the patch to the river, the occurrence of permanent versus temporary connections to the river, and the size and shape of the waterbody. The waterbodies are a major source of habitat complexity in the riverscape that are reshaped after major flooding, such as the 1,000-year rain event and associated flooding in South Carolina. We present our preliminary findings on the post-flood fish communities of two riverine systems.

Methodology

The recent 1,000-year rain/flooding has reconnected riverine habitats across the riverscape and provided us with a unique opportunity to sample along the Saluda-Broad-Congaree river system and the Edisto River in order to make comparisons with pre-flood collections. The main method used for sampling the fish communities was electrofishing (boat and backpack) and hook-and-line. Fish samples were identified to species and measured. Most samples were returned to the water, but representative samples from certain species were saved on ice and returned to the Fish/Fisheries Conservation Lab for further processing for age, reproductive stage, and total mercury (Hg) concentration in edible muscle tissue.

Results

A total of 60 fauna species were collected from seven sites along the Edisto River comprising 14 fish families and four invertebrate families. The top three most species-rich fish families were minnows (Cyprinidae with 18 species), sunfishes (Centrarchidae with 13 species), and freshwater catfishes (Ictaluridae with five species). Species richness increased as sampling location moved downstream and the adjacent river channel widened. The species that occurred at the most sites were pirate perch (all seven sites), mosquitofish (all seven sites), American eel (six sites), bowfin (five sites), largemouth bass (five sites), bluegill (five sites), redfin pickerel (five sites), spotted sucker (five sites), and warmouth sunfish (five sites). All oxbow lakes sampled as part of this study were reconnected with the main river channel and all experienced an increase in species richness post-flooding.

Species examined for Hg bioaccumulation within the Saluda-Broad-Congaree system included bluegill sunfish, redbreast sunfish, black crappie, white perch, yellow perch, and largemouth bass, and those examined from the Edisto River system were bluegill, redear sunfish, dollar sunfish, pumpkinseed sunfish, black crappie, flathead catfish, and redfin pickerel. Saluda-Broad-Congaree system and Edisto River fish Hg concentrations ranged from 0.03-0.76 and 0.26-2.03 ppm, respectively. Flathead catfish, an introduced species in the Edisto River and commonly targeted and consumed species by recreational anglers, accounted for the highest Hg levels, and fish age and size correlated significantly with Hg concentration.

Summary and Conclusions

Oxbow lakes in the Edisto River system experienced increases in species richness as a result of the flood event reconnecting lakes to the river channel. Fish samples will continue to be processed for growth and reproduction in order to determine if the influx of organic materials into the riverine systems resulted in enhanced growth and/or reproductive output. Fish muscle samples from pre-flood collection efforts will be analyzed for Hg concentrations and then compared with post-flood data to determine if flooding impacted Hg bioaccumulation in several species.

Examining the Role of Twitter as a Response and Recovery Strategy During the #SCFlood in October 2015

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Introduction

Social media plays an increasing role in response to emergency situations. The general public has high expectations for quickly delivered information during emergencies. Social media use is becoming commonplace with 74% of adults using Facebook or Twitter. Social media is a low-cost and quick way to reach millions of people, making it ideal for emergency situations as a means of information exchange and guiding recovery efforts. Social media allows correction of miscommunication and for users to share their safety status and alert emergency response teams to previously unidentified needs. Further, social media provides a forum for community strengthening during and after an emergency. The historic rainfall and flooding in the Midlands region of South Carolina on and around October 4, 2015, presented an opportunity to understand the role of social media.

Methodology

The overall goal was to examine the role and use of social media as a response and recovery strategy during the 2015 SC flood in the Midlands region. Initially, we planned to focus on Facebook and Twitter; however, the volume of postings resulted in a specific focus on the use of Twitter only. We examined tweets using the hashtag #SCFlood during four time periods: before (September 30-October 2, 2015), during (October 3-4, 2015), immediately after (October 5-14, 2015), and six months after (April 2016). Tweets were retrieved and coded in NVIVO software by three independent coders who, along with the overall research team, developed a codebook. Approximately every tenth tweet was coded for the first three time periods, and all tweets were coded for the last time period. Emergent themes were identified across and within each time period. An iterative process was used.

Results

Coding of tweets was descriptive and thematic guided by the final codebook. Descriptive coding identified the type of user, time period, user location (if known), content location (if known), and reach (retweeted or liked). Thematic coding examined the content and meaning of tweets. Common emergent themes were weather conditions (with most posts occurring immediately before and during the flood), devastation description (both built and natural environment devastation described), resource distribution (with water distribution being the most commonly coded resource mentioned), volunteerism (including reports of volunteer experiences and opportunities to volunteer), actions to reduce threats to health, and appreciation. Posts mostly originated from individual users, followed by media outlets, governmental agencies, and non-profit agencies. We were able to determine the user location of tweets for 25% of the posts. Of location identified posts, 64% were from a user in the Midlands, which was the focus of our geographical interest. Results of our thematic analysis will also be presented visually with the use of word clouds to demonstrate the most frequently used and most important words depicted in larger font size. In addition, while we did not code images, we use images included in tweets to emphasize emergent themes. Our results demonstrated broad usage of Twitter across the four time periods, with the fourth period comprising the fewest examples.

Summary and Conclusions

Twitter was utilized widely as a communication tool in the response and recovery efforts following the historic flooding in the Midlands region of South Carolina in October 2015. Community members, governmental agencies, media outlets, and non-profit organizations all utilized Twitter to provide information on weather conditions, describe areas of environmental destruction, alert people to where water and other resources could be obtained, give people information about volunteer opportunities, provide tips on how to reduce harm and stay safe, and show appreciation for one another. Based on this information, our next steps will include meetings with key stakeholders, such as the South Carolina Emergency Management Division and others, to disseminate our findings and to discuss how to leverage the use of social media in the future.

Learning From Lived Experiences: Disaster Preparedness and Response During South Carolina's Historic 2015 Flood and Impacts on People With Disabilities

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Introduction

The 1,000-year flood of 2015 impacted thousands of South Carolinians statewide. Among those most severely impacted are persons with disabilities. Although South Carolina rapidly responded to the crisis for the population at large, for persons with disabilities, South Carolina was largely unprepared. Data revealed challenges and areas of opportunity for equal access to information and services. This research focused on identifying gaps in service and best practices to effectively meet the needs of people with disabilities, a demographic that comprises over 13.9% of the total population (Erickson, Lee, and von Schrader, 2010).

Methodology

The study employed a mixed-methods approach, including surveys of flood survivors with disabilities and emergency responders and volunteers. Surveys were distributed through Able SC to a network of agencies which work with persons with disabilities, the United Way network of agencies, Portlight, and American Red Cross. Usable survey responses of persons with disabilities totaled 123. Despite repeated attempts, only 17 emergency responders and volunteers responded to the survey. Qualitative data was collected from survey respondents who volunteered to take part in follow-up interviews. Of 23 volunteers, seven flood survivors were interviewed. Additionally, seven employees of Able SC were interviewed. Descriptive analysis was performed.

Results

Of the 123 respondents with disabilities, 67% were females and 33% males. Eighty-two percent of persons in evacuation zones reported evacuating as directed. Fifty-three percent of respondents reported receiving evacuation instructions. Of that 53%, 6% reported instructions that were difficult to understand. The majority of respondents (70%) reported that the time in which government officials responded to the flood was reasonable or good. Only 13% indicated poor governmental response to the flood. Nine percent of respondents indicated that the government or local officials did not know how to effectively meet the needs of persons with disabilities. The majority of respondents indicated that they did not receive help from any individual or group. Those seeking assistance received it primarily through the Federal Emergency Management Agency (FEMA) (40%), church-based organizations (18%), and American Red Cross (16%). Potential areas of improvement include greater awareness by volunteers regarding best practices for working with people with disabilities in crisis, improvements with communication and accessible modes of communication and services for persons with physical disabilities. One specific concern was a lack of response or promised services by FEMA and other organizations six months after the disaster. Qualitative data collected during these interviews reiterate the importance of emergency preparedness and offer compelling evidence of: the biopsychosocial impact of the flood; the failure of infrastructure to meet the needs of the community, including the needs of persons with disabilities; and the need for collaboration between persons with disabilities and emergency response personnel.

Summary and Conclusions

The primary recommendations of this research are: 1. Strengthening or developing services to ensure equal access to all services and resources during the next crisis. 2. Developing training for disaster response personnel to appropriately assist persons with disabilities. Results highlight areas of needed improvement prior to the next natural disaster. Disability awareness and emergency planning training is essential for professionals, volunteers, and persons with disabilities. The research highlights that training needs to occur prior to the next natural disaster. It also highlights the need for ongoing research related to post-disaster service delivery to persons with disabilities. A secondary outcome is a video archive of the lived experiences of persons with disabilities and emergency service personnel during and after the flood.

The Social Network Resiliency of Older Adults During the October 2015 Flooding

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Introduction

Research has shown that community-dwelling elderly are among those most vulnerable in and after a disaster. Pre-existing health conditions and limited economic and social capital often reduce the capacity of the elderly to respond to and recover effectively from a disaster. Social capital refers to the informational (e.g., legal assistance), instrumental (e.g., financial aid, housing), and expressive (e.g., emotional support) resources that individuals or groups have available and accessible through their social networks. Yet, little is known about the types of resources that the elderly may need during or after a disaster and the network ties on which they may rely to access those resources. The primary aim of this research was to document the various forms of social capital that the elderly were able to access and mobilize during the October 2015 floods

Methodology

Mixed methods, including survey and social network methods, were used to collect data from a convenience sample of flood-affected, community-dwelling elderly. Questionnaires were administered to collect a range of information about elders' (a) exposure to the disaster, (b) socio-economic and -demographic characteristics, (c) social networks, and (d) health conditions. A name generator/interpreter instrument was used to collect social network data on those network members providing assistance to the elderly during the flooding. For this presentation, descriptive statistics were calculated for key variables. Chi-square and ANOVA tests were also conducted to assess differences between those elderly who reported three or more chronic conditions and those with less than three conditions.

Results

The convenience sample consisted of 25 flood-affected, community-dwelling older adults. Their average age was 72.3 years. Approximately 32% self-identified as African-American with the remaining 68% identifying themselves as Caucasian. Roughly 80% of the participants reported that their home was flooded, with 40% having had to move either temporarily or permanently. Participants reported needing financial assistance (64%), food (44%), and emotional support (40%).

Participants named a total of 110 network members or alters. The average network size was 5.2 with 56.1% being female and 50.5% considered friends. Alters tended to know the other alters in participants' networks. Relatives tended to reside in another city than the participant (45%) but friends were often in the neighborhood (43.4%) or from participants' churches (28%). Participants reported receiving emotional support (84.2%) and food (49.1%) but low levels of financial assistance (21%) from their alters. When provided, financial assistance tended to come from kin.

Sixty percent of participants had three or more chronic conditions. Hypertension (86.7%), high cholesterol (86.7%), and arthritis (66.7%) were the most common conditions. Elderly with three or more chronic conditions tended to have a higher percentage of kin and neighbors in their networks, and received a higher percentage of emotional support. Those elderly with few conditions reported greater levels of need than those with more conditions. This difference was also reflected in the higher percentage of instrumental support received from their alters.

Summary and Conclusions

The community-dwelling elderly in our sample accessed a range of resources through their social networks. While emotional support was one of the main resources accessed, instrumental support in the form of food and moving was also important. Those participants with more chronic conditions accessed different types of resources than those with fewer conditions (e.g., instrumental versus emotional), but these differences in resource mobilization appear due to the particularities of the flood impact. Given that only 20% of the elderly in our sample reported using social media during the disaster, understanding the sources and types of support that elderly networks provided during and after the flooding is critical. Developing disaster programs that leverage the social networks of the elderly may facilitate their preparedness and resiliency over the disaster cycle.

Experiences of Latinos Affected by the Floods in Columbia, SC

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Introduction

The University of South Carolina Consortium for Latino Immigration Studies (CLIS) and particularly the PASOs programs, were inundated with requests for culturally and linguistically appropriate assistance and support from local organizations and Hispanic/Latino residents who were affected by the 2015 SC floods. It was apparent to us that a need for more coordinated efforts existed. Examining the capability of emergency preparedness personnel and organizations to communicate effectively with vulnerable limited English proficiency (LEP) populations about a catastrophic event as well as the experiences of Hispanics/Latinos that were affected by the flooding was of paramount importance to help us better understand future needs of all parties involved.

Methodology

We conducted 16 interviews with agencies/organizations and 100 surveys with Latinos described as follows:
1. The stakeholders included Hispanic-serving organizations, religious organizations, non-profits, government agencies, law enforcement agencies, and media; with the intention to: (a) provide a better understanding of how South Carolina communicated information to the growing LEP Hispanic/Latino community before, during, and after the catastrophic event; (b) identify current needs of the Hispanic/Latino population as it relates to emergency preparedness and the aftermath of a natural disaster; and (c) identify reasons why emergency preparedness communication strategies are sometimes not reaching this population or why they are not understood.
2. Surveys explored the experiences of Latinos before, during and after the floods to identify gaps in services.

Results

Key findings from the interviews with stakeholders were:
1. The limited English speaking, Latino community was not specifically reached out to and prepared before the 2015 flood.
2. Services during the 2015 flood were predominantly in English-only.
3. Charitable organizations were burdened by abandoning their day-to-day mission in order to respond to huge numbers of applicants, including LEP populations.
4. Although government agencies do have the capacity and personnel designated to translate into Spanish, it is not effectively reaching the community.
5. The LEP population is discussed much more now than in previous years, but it is not yet a priority.
6. Most organizations do not know much about the Latino population in the Midlands.
7. Many organizations note a communication barrier between Latinos and organizations that have not yet established trust in the community.
8. Those who have assisted Latinos have a definite appreciation for the community spirit demonstrated by the Latino community at the time of the flood.
9. Our sheriffs departments had a very positive experience with the LEP Latino community at the time of the flood.
10. The 2015 floods exposed previous infrastructure gaps within state emergency planning and utilization/management of resources.

Findings from the surveys with Latinos who were affected by the floods are:
1. 27% owned the house/trailer
2. 22% and 28% spoke or read none or some English respectively
3. Median education: nine years
4. 63% from Mexico
5. 72% did not know what to do, were not prepared before the floods
6. 74% did not know anything about the floods or learned about it when it started raining constantly
7. 54% learned about the floods via TV, friends, neighbors or family
8. 64% had to evacuate; of those, 71% went to friends' or family members' homes
9. 51% reported their homes were damaged but in livable conditions
10. 57% rated the assistance received to be worse when compared to others who were also affected by the floods

Summary and Conclusions

Limited English speaking Latinos were not specifically reached out to and provided information before the 2015 floods. Latino populations affected by the floods reported lack of communication between the government/media and the population as a significant area of concern. Most agencies provide services exclusively in English and only materials considered to be of life-or-death importance are translated into Spanish. Charitable organizations felt that communities, including those who spoke little or no English fell through the cracks. Policy changes addressing limited English speakers are not a priority in the state. Organizations and other state agencies need to establish trust with Latino populations and one important aspect to gaining this trust is hiring bilingual and bicultural staff.

Disaster Response, Public Safety, and Community: The Hidden Costs of School Closures

Tamara Sheldon, Department of Economics
Melanie Gall and Larianne Collins, Department of Geography

Introduction

Research on the economic costs of unscheduled, temporary school closures is very limited. Few studies have investigated the economic burden of temporary closures with nearly all of these studies modeling hypothetical closures as a response to a public safety threat, such as a pandemic outbreak, compromised water supplies, or terrorism. Post-disaster case studies are largely absent from the existing body of research both on school closures and on costs from natural disasters. Traditionally, the latter evaluates either direct losses from a disaster such as property damage or fatalities, or conducts more macro-economic assessments with a focus on the business sector. Schools do not produce goods or services and are therefore generally excluded from post-disaster economic impact assessments.

We hypothesize that the indirect costs of the 2015 floods are higher than the direct damage and that the costs of temporary school closures place a significant burden on communities. Prolonged school closures increase the economic burden on households thereby slowing community recovery as indicated by research elsewhere.

Methodology

We administered an online survey using Survey Monkey to residents in the three school districts within Richland County. From November 2015 through April 2016, we solicited responses via outreach on social media, the local news, and emails to parent-teacher organizations and day care centers. Our final sample consisted of 208 completed responses from adults residing in the Columbia metropolitan area. As part of the survey, respondents indicated how many hours of work they missed each day in the two weeks following the October floods due to various reasons, including school closures, workplace closures, and road closures. Respondents also estimated additional childcare expenses they incurred during this period and provided demographic information along with their salaries or hourly wages.

Results

Using equal survey weights, which over-represents white, highly educated respondents, resulted in a mean of 36 hours of work missed, which translated to $1,325 in lost productivity. Post-stratifying on race, which makes the survey sample more representative of the actual population, resulted in a mean of 45 hours of work missed, which translated to $2,175 in lost productivity. In general, hours of missed work were lower in the first three days after the flood, which is likely due to the floods starting on a Saturday. Considerably more hours of work were missed during the first week following the floods (20-26 hours) than the second week (four-six hours). The majority of hours of missed work were due to school or workplace closure (10-13 each for the respondent) with only an hour or so on average missed due to road closures or other reasons.

Respondents spent $15-20 on average for additional childcare and activities. Respondents left children with family or friends (unpaid) for an average of two-three hours, but only took children to work for less than an hour on average.

As of the 2010-2014 census, there were 144,647 households in Richland County, SC. Multiplying the number of households by the $1,324.54 in indirect costs from lost productivity plus the $17.60 in additional childcare costs/activities resulted in an estimated total indirect loss to households in Richland County of $194 million using equal survey weights. Post-stratifying on home ownership produced an estimate of $216 million, and post-stratifying on race results in an estimate of $317 million.

Lastly, we utilized a multinomial logit model using the data from the choice experiment and found that households are willing to pay $9.10 on average ($4.94-$11.90 with 95% confidence) to avoid one additional school closure, and $7.43 on average ($0.78-$10.06 with 95% confidence) to avoid one additional late start. This suggests that households' disutility for a late start is almost as great as their disutility for a school closure.

Summary and Conclusions

Since October 2015, the Federal Emergency Management Agency disbursed nearly $90 million in individual assistance and $72 million in public assistance across the affected counties in South Carolina. Within the City of Columbia, residents received about $18 million dollars in individual assistance and the Community Block Development Grant program provided an additional $20 million in funding to the capital city to compensate for direct damage. However, none of the costs from school closures ($216 to $300 million) are reimbursable. This means that indirect costs from natural disasters are externalized leaving the public, and particularly vulnerable populations such as single, female-headed households or the poor, to bear those costs. It is important to note that our estimates excluded indirect losses in the business sector, which collectively may be at least one order of magnitude higher than the direct damage. To minimize the externalization of school closure costs school districts should re-evaluate their policies and examine the feasibility of partial district openings or late starts or moving to remote/alternate school sites. Temporary school closures are not only a question of public safety or emergency management concerns, but implicitly carry ethical undertones with some families able to afford school closure while others cannot.

New Measures for Quantifying Importance of Links in a Transportation Network

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Introduction

Transportation networks are vulnerable to natural disasters such as floods, tsunamis, earthquakes, etc. Interdependencies between the transportation system and other critical infrastructures necessitate protections to achieve system resiliency. In order to increase a network's resiliency, the important links need to be identified. This study proposes two new measures to quantify link importance. It extends previous work by considering the extra distance traveled by road users when a link is disrupted, the traffic volume on the disrupted link, and the economic losses due to loss of the link. To assess the effectiveness of the proposed measures, they are applied to a transportation network in South Carolina using data from a recent 1,000-year rainfall event.

Methodology

To quantify a network's vulnerability, this study uses a measure called importance, which is defined as the set of consequences resulting from a link failure on the network. In previous works, two aspects of link importance are considered: level of usage, in terms of number of users relying on a particular link for daily trips, or the annual average daily traffic (AADT), and consequences on the network in terms of an increase in cost due to link closures. In previous studies, the cost component of importance is simply the difference in travel time between normal and disrupted networks. This study extends the cost component calculation by incorporating the extra distance traveled by road users, AADT on the affected road(s), and the economic losses due to loss of link(s). Two new importance measures are developed.

Results

1. Two new importance measures have been developed in this study: IM1 and IM2.
2. Both IM1 and IM2 consider traffic volume and the extra distance traveled by road users in the cost calculation. Moreover, IM2 takes into account the economic impact of road closures. IM1 and IM2 were calculated for the 22 closed roads or bridges in Richland County.
3. To evaluate the developed IM1, it is compared against the importance measure developed by Rupi et al. (2015). Due to the inclusion of extra distance traveled due to closures and AADT in the cost calculation, the value of global importance in IM1 is very different from that of Rupi et al. Using our IM1, roads with lower traffic volume (AADT) are ranked to be of less importance than Rupi et al.'s approach. This finding corresponds to intuition. It can be concluded that roads located in the densely populated areas have higher importance values, and roads located in rural and less populated areas (even with longer detours) have lower importance values.
4. The total economic losses associated with all measured road closings in Richland County resulting from the October 2015 flood is estimated to have been between $949,000 and $3.8 million. The economic losses are associated with between 8 and 30 jobs and between $324,000 and $1.3 million in labor income for South Carolinians.
5. Between IM1 and IM2, roads that have higher economic impact on the network are ranked higher by IM2 than IM1.

Summary and Conclusions

This study developed two new measures to quantify link importance, IM1 and IM2. These measures consider the extra distance traveled by road users when a link is disrupted, the traffic volume (AADT) on the disrupted link, and the economic losses due to loss of the link. To assess the effectiveness of the proposed measures, they are applied to a transportation network in South Carolina using data from a recent 1,000-year rainfall event. The results indicate that the proposed measures capture the essence of link importance much more accurately due to accounting for the stated factors. The proposed measures can thus better assist state agencies in prioritizing the important links to maintain or enhance in order to improve the overall network resiliency.

A Foundational Information Infrastructure for Future SCFLOODS Impact Research

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Introduction

Research on the 2015 SC floods addresses the archiving of volatile data for subsequent research and analysis. But it is critical that this data be sufficiently structured to support future work with big data and intelligent algorithms. Traditional data tables have units, accuracy and defining indices scattered in subtitles, footnotes, row and column headings and often imbedded in text. We developed a standard ("MetaNumber" (MN)) for archiving numerical data that attaches to each numerical value, its units of measurement, numerical accuracy, exactly defining metadata, and unlimited supplementary metadata tags, along with software for the automated unit (dimensional analysis) and uncertainty processing and naming conventions. This proposal 1. develops the software tools for archiving data using this standard, 2. archives 2015-16 SC weather station data for future use, 3. provides the application program interface (API) calls that allow the MN processing using API calls from the user's software programs, and 4. creates new data collection methods.

Methodology

1. The MN software standard and associated software was developed under a USC ASPIRE II grant. 2. The SC weather data was downloaded from the National Oceanic and Atmospheric Administration (NOAA) website and reformatted in MN format. Specifically, the data captured, in different intervals include: (a) station name, (b) latitude, (c) longitude, (d) elevation, (e) date, (f) time , (g) precipitation, (h) temperature high, and (i) temperature low. This data was reformatted into a comma separated value file with unique row and column headings described below. 3. The API calls were developed for Java, C, and other languages to allow the MN cloud program to be called from within the user's program for processing. 4. A new data collection phone application was prototyped that captures video, audio, longitude, latitude, and date-time of environmental events (such a dam failures) with automatic archiving and dispatch notification.

Results

The objective of our MN numerical standardization is to support unambiguous reading of data by both humans and computer. Generally this means that for two-dimensional tables, the first row and the first column each must have a unique name which, along with a unique table name, allows a value to be retrieved with the expression (for the default server) as [table name_row name_column name]. This expression can be used to retrieve that value for processing as a variable name in mathematical expressions. The units are attached to each value such as 34.5*inch or 45.3*mm and the numerical uncertainty is captured as the number of stated digits. All unit conversions and numerical uncertainty are automatically processed by the software allowing any valid mixtures of units with any prefixes. For the weather data we named each table with the NOAA table station name and used the date(time) to label the rows with the columns giving the property shown. While precipitation in mm or inches was easily managed, temperature highs and lows were more challenging. We devised functions DC(value) and DF(value) which allowed the Celsius and Fahrenheit values to be easily read by both humans and automatically converted to Kelvin for data processing in the format 345.6*k. Functions for reverse conversion were also created. Longitude and latitude were converted to decimal format for simplicity and functions for reverse conversions to degrees, minutes, and seconds were created for human use when required. We experimented with creating a single table for weather by using the NOAA table station name combined with the datetime but decided it was too complex for easy use. We originally intended to also obtain the electrical usage of individual meters from the three primary companies (SCANA, Duke, and Santee Cooper) but they would not provide the data due to privacy concerns and for liability reasons. However they do archive such data internally. To enable future rapid scientific data capture we have also prototyped a phone app capturing video, audio, longitude, latitude, datetime, user, and incident type with continuous archiving to a server with notification to a dispatch unit.

Summary and Conclusions

It is hoped that 1. our NOAA weather data MN archive will demonstrate the utility of the MN standardization and 2. that our tools for standardizing scientific data for future automated processing will prove valuable. 3. We also believe that the phone app which we have prototyped can be of great value in ordinary scientific data capture as well as emergency management crisis event documentation and notification. 4. Our team is available to assist other SC FLOODS grants in archiving and testing their data in the MN format. Users can access information on MetaNumber through www.metanumber.com under "resources" and also via our website www.asg.sc.edu.

Rebranding South Carolina in the Aftermath of the Historic Flood: An Examination of South Carolina's Projected and Perceived Images on Travel Decisions of Potential Tourists

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Introduction

Tourism and hospitality are the top income and employment generators in South Carolina, especially in the coastal regions. According to the SC Department of Parks, Recreation and Tourism (SC PRT), "spending on core tourism activities in South Carolina totaled $14.28 billion in 2014 while supporting one out of 10 jobs" (extracted from SC PRT web site). Tourism destinations like South Carolina are vulnerable to natural disasters not only because of their direct negative effects to the tourist trade, but also due to damage to perceived destination image for immediate and future travel to the state. This study examines South Carolina images' effect on tourists' travel decisions after historic floods in October 2015.

Methodology

A stratified sample of a total of 1,106 "potential tourists" was recruited by a contracted online research company, Qualtrics, during the month of March, 2016. For this study, potential tourist is defined as any individual who plans to take a pleasure vacation trip in the next 12 months or someone who traveled for the same reason in the past 12 months. These tourists were located in heavy tourist markets for South Carolina like North Carolina, Georgia, Virginia, and New York. The resident sample contained 840 residents of heavy tourist-receiving regions of the state stratified according to the percentage of state income based on tourism activity. Both online surveys took about 12-15 minutes to complete. Overall effective response rate was 75%.

Results

1. The majority of the visitors traveled to South Carolina for the purpose of leisure/vacation (71.5%) while only a small percentage traveled for business (3.1%) or for both leisure and business (8.4%).
2. Out of the respondents who had intentions to travel to South Carolina in 2016, the majority of people went ahead to South Carolina as planned (53.5%), while the remaining did not complete their trip as planned yet (46.5%). Among those who did not travel to South Carolina as planned, 35% or one out of three potential travelers have either canceled or postponed their trip due to an uncertain future; this figure may amount to about 10 million potential tourists when 2015 total numbers are used as base.
3. Out of the 807 respondents who would visit South Carolina within the next 12 months, the majority (54%) would visit the Myrtle Beach Area and the Grand Strand (Horry, Georgetown counties), followed by Historic Charleston (Charleston, Dorchester counties) (37.9%). The Capital City and Lake Murray (Lexington, Richland, Saluda counties) are the least popular destinations with only 6.6% of the potential travelers wanting to visit.
4. The good news is that out of the total respondents, the majority are likely to recommend visiting South Carolina to their friends or relatives (70%). Only a small percentage of them would not recommend going to South Carolina to someone they know (4.5%). Thus, considering the October floods and the recovery efforts, most people are still likely to recommend South Carolina as a travel destination to others, indicating a strong brand.
5. Travelers' altruism and flood experience were found to have the strongest influence on the potential travelers' motivations to travel to South Carolina within 12 months.
6. The majority (84%) of the tourists (n=184) who canceled their vacations are visitors who have visited South Carolina before and are mainly female (70%).
7. Those people who have either canceled or postponed their trip to South Carolina have more safety and health concerns than those who went ahead with the trip to South Carolina in 2016.

Summary and Conclusions

For those who canceled their trip, 27% indicated that they are unlikely to travel to South Carolina within 12 months while of those who postponed the trip, 14% are unlikely to visit South Carolina in the following year. Although most of these non-travelers indicate that they are likely to travel, the local tourism industry still needs to attract those who are unlikely to travel to South Carolina within 12 months. Nearly 70% of the cancelations/postponements are from females, yet there are no differences between males and females in terms of their total cognitive images of South Carolina tourism attractions and facilities, services and value, and tourist access and recreational amenities.

The Economic Impact of the 2015 South Carolina Flood

Douglas Woodward and Joseph Von Nessen, Darla Moore School of Business

Introduction

This research project evaluates the economic resiliency and stimulus effects of the historic 2015 rainstorm and flood in South Carolina. In the wake of natural disasters like the 2015 flood, many regions face substantial losses of wealth (mostly property and infrastructure damage). As these regions begin the rebuilding process, some sectors of the economy experience temporary gains in economic activity, generating employment and income, as a result of insurance claims and other short-term income flows.

Local businesses benefit from the stimulus of new spending during the reconstruction period that typically begins three to six months after the disaster. By examining the sources and dollar amounts of this new spending, the total economic impact of the stimulus can be estimated utilizing a customized input-output model of the South Carolina economy.

Methodology

In order to determine the economic impact of all new spending activity that will occur as a direct result of the 2015 flood, data were first gathered on the estimated total dollars that flowed into the state's economy as a result of disaster relief efforts. This included Federal Emergency Management Agency (FEMA) assistance, small business administration loans, housing restoration, road repairs, and various insurance claims. These data represent the direct effects of the flood stimulus.

These expenditures also lead to additional job creation and economic activity throughout South Carolina by way of the economic multiplier effect, which includes further in-state spending that occurs when dollars are spent with local businesses and then are re-spent by these businesses on in-state suppliers and on employees. The direct effects plus all multiplier effects yield the total impact of the flood stimulus.

Results

According to the most recent data available, approximately $1.2 billion in new direct spending activity will occur during 2016 as a result of the South Carolina flood. This includes each of the following: FEMA disaster relief, small business administration loans, housing restoration (via the South Carolina State Housing Authority), road repairs, agricultural industry insurance claims, and various property and casualty insurance claims. Once the money flows into the state, these funds will be spent locally on repairs and rebuilding efforts. Our model of the regional economy estimates that this new spending will generate approximately 12,000 jobs and $435 million in labor income for South Carolinians. This level of direct economic activity also leads to economic multiplier effects totaling an additional 8,300 jobs and $305 million in labor income. These impacts are temporary. Nevertheless, South Carolina can expect to experience a stimulus effect in 2016 that will generate a total economic impact of $2.2 billion, which is associated with 20,246 jobs and $739 million in labor income. The majority of this impact is occurring within the construction and retail sectors.

Placed into context, this implies that South Carolina employment growth in 2016 is about 0.2% higher than it would otherwise have been without the flood stimulus. This effect is significant given the recent slowdown of the U.S. economy, which has led to a slight reduction in the rate of South Carolina's employment growth over the last 12 months. The flood stimulus has helped to mitigate this overall impact.

Geographically, this $2.2 billion stimulus will be distributed primarily in a 22-county region that encompasses Charleston, the Midlands, and their surrounding areas. The counties experiencing the largest stimulus effects as a percentage of their total economy are Orangeburg (5.7%), Kershaw (5.6%), Bamberg (3.4%), Newberry (3.3%), and Sumter (2.7%).

Summary and Conclusions

Following the 2015 South Carolina flood, both federal and private dollars have been injected into the state's economy through various disaster relief efforts and insurance claims, and as a result, have generated a stimulus effect for South Carolina in 2016. The estimated total economic impact of these efforts will reach over $2.2 billion by the end of 2016, which is associated with more than 20,000 jobs and $739 million in labor income. This implies that employment growth in South Carolina is currently receiving a temporary boost of approximately 0.2%, which is significant given that South Carolina's overall rate of employment growth in 2016 has not seen any improvement over the last year. Thus, the stimulus effect has helped to keep the state at an overall level of activity that is comparable to what was observed in 2015.

Investigation of Mold Infested USC Buildings Affected by the October 2015 Flood: Comparison With Original Mold Infested Areas

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Introduction

Several buildings on the USC Columbia campus have consistently suffered from mold problems. These molds have not been identified to the species level before. The data is essential for USC Facilities to understand the health issues that may emerge due to indoor air contamination with mold spores and adopt the best strategies for remediation. In this pilot study we have identified the predominant species in three of the most mold-infested USC buildings. We have also examined whether any new mold species have emerged specifically due to the SC floods.

Methodology

Indoor spore samples were collected by standard plate collection method on potato dextrose agar plates. After seven days of growth on the plates, the single mold colonies were isolated, catalogued and stored for identification and future work. DNA was isolated from each colony. For phylogenetic analysis, polymerase chain reaction amplification of the ITS1 region of the genome was performed and the resulting amplicons sequenced. Multiple sequence alignment was performed using the Basic Local Alignment Search Tool (BLAST) from National Center for Biotechnology's Genebank database. The associated taxa derived from this analysis were then used to investigate the evolutionary relationship between the taxa using the neighbor-joining (NJ) method and evolutionary distances in this phylogram were computed using the maximum composite likelihood method and evolutionary analyses were conducted in MEGA6 software.

Results

We have identified 28 different mold species in this study that are associated with allergies and mild respiratory problems in immunocomprised individuals. Mold colonies that emerged due to SC floods were predominantly *Clostridium halotolerens*, which is a mold that has been identified as well in other mold-infested buildings not affected by SC Floods.

Summary and Conclusions

Although SC Floods did not introduce any new species of molds in USC buildings, the already existing indoor molds in some buildings may have significant health impacts on students and staff with immune dysfunction, and therefore need regular monitoring.

Virulent *Vibrio vulnificus* Densities in Winyah Bay Waters

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Introduction

Vibrio bacteria occur naturally in coastal environments, meaning that changes in physical parameters, such as a change in salinity, can result in higher *Vibrio* densities in the environment. The densities of one pathogenic *Vibrio* species, *Vibrio vulnificus*, were determined in this project. *V. vulnificus* infects open wounds to cause necrotizing fasciitis ("flesh eating disease"). The mortality rate of this virulent bacterium is a shocking 50%. The historic flood event in South Carolina gave us a rare opportunity to determine how virulent *V. vulnificus* population densities change with a rapid decrease in salinity. Data from this project could be used to better prepare health care officials in the event of another flooding event.

Methodology

This project compared *V. vulnificus* densities from post-flood Winyah Bay waters to 2012 pre-flood waters. Winyah Bay is located in Georgetown, SC and is the confluence of three rivers. The historic rain event caused significant flooding in all of these rivers; sampling was conducted immediately while waters were still high. Water samples were collected using the same procedures as our 2012 sampling. Three locations in Winyah Bay were sampled, along with six river locations. Water quality field parameters were measured using a YSI multiparameter sonde. Water samples were taken back to Columbia, SC for *Vibrio* extractions. Densities of vibrios were observed and compared to pre-flood waters. Polymerase chain reaction (PCR) gene amplification was then performed to differentiate between pathogenic (disease-causing) and non-pathogenic strains of *V. vulnificus.*

Results

Hypothesis tested: *V. vulnificus* densities will be significantly higher post-flood due to the historic rain event lowering Winyah Bay's salinity. *V. vulnificus* has an optimal salinity of 5-20 ppt.

Sampling of flood waters occurred on November, 5, 2015, about 30 days after the initial rain event; flood waters were still high. Nine total locations were sampled, with three in Winyah Bay and six in river locales. At each sampling site, water samples were collected for later *Vibrio* extractions, and water quality field parameters were measured using a YSI multiparameter sonde, including temperature and salinities. Post-flood water data was compared to previous data from October 29, 2012, which will hereafter be referred to as "pre-flood." Salinities of the sampling sites were significantly lower in post-flood waters, as expected. Pre-flood waters had an average salinity of approximately 13 ppt, while the post-flood waters were effectively fresh water, with hardly any salinity detected (average of 0.05 ppt). The temperatures between pre- and post-flood waters were not significantly different; both water samplings had an average temperature of approximately 20 degrees Celsius. There was significantly less *V. vulnificus* in post-flood waters, compared to pre-flood water.

PCR gene amplification was performed on pre-flood *V. vulnificus* isolates in order to establish a baseline data set. Not all strains of *V. vulnificus* are capable of causing an infection; in order to differentiate between pathogenic and non-pathogenic strains, we amplified the virulence-correlated genes, vcgC and vcgE. The vcgC gene is correlated with pathogenic *V. vulnificus* and vcgE is correlated with non-pathogenic strains. We screened approximately 500 strains; 20% of them were positive for the vcgC gene, and are presumed to be pathogenic. The other 79% tested positive for the vcgE gene. A few (1%) *V. vulnificus* strains recovered amplified both vcg variants. This is, to our knowledge, the first report of a *V. vulnificus* strain amplifying both vcg variants.

Summary and Conclusions

We hypothesize that *V. vulnificus* was not recovered from post-flood waters due to the extremely low salinities. The historic rain event decreased Winyah Bay salinity to lower than *V. vulnificus* optimal salinity, which is 5-20 ppt. Post-flood waters were effectively fresh water, which is anything lower than 5 ppt. Vibrios have been observed entering a viable but not culturable state (VBNC). In this state, the cells are still alive but have very low metabolic activities and don't readily grow in laboratory culture, making extractions problematic. It is possible that the *V. vulnificus* cells entered this state due to stress from the sudden, sharp drop in salinity. In this state, we would not have been able to detect the vibrios with our methods, which accounts for significantly lower *V. vulnificus* numbers found in post-flood waters.

School Mental Health Response and Resilience During the 2015 South Carolina Floods

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Introduction

Due to the infrequency of natural disasters, school personnel may lack knowledge or skills to effectively address a disaster. Nevertheless, educational systems are expected to have a plan to address the needs of students, families, school personnel, and the community (DeVaney, Carr, and Allen, 2009). School counselors are expected to assume a leadership role in creating and implementing response plans before, during, and after a crisis (e.g., natural disaster) (Studer and Salter, 2010). DeVaney et al. called for more research examining the effects of disasters on children, teachers, and schools as well as the roles of school personnel in providing services to those traumatized by the disaster. Therefore, the purpose of this study is to explore the experiences of school mental health professionals (e.g., school counselors) in responding to the South Carolina floods.

Methodology

We used consensual qualitative research (CQR; Hill et al., 1997; Hill, Knox, Thompson, and Hess, 2005) for this study. The primary components of CQR include (a) the use of open-ended questions, (b) consensual agreement within the research team regarding the data analysis, (c) the participation of an internal and external auditor throughout data analysis, and (d) identifying domains, core ideas, and categories to utilize a cross-analysis. We examined the subjective experiences of 14 school counselors in order to further understand the mental health effects individuals endured during and after the flood, and how this process affected their well-being and resilience within a school system.

Results

We describe the findings of the investigation using domains (topics used to group data; Hill et al., 2005) and categories used to conduct a cross-analysis to support the findings. We coded 14 interview transcripts to develop our list of seven domains. Once the domain list was finalized, we created core ideas from each participant statement within each domain. The core ideas were grouped into 25 categories. The research team conducted a cross-analysis of the core ideas and categories within each domain. We labeled categories to signify frequency and to characterize the data. A general category label was used to signify 10 to 14 participants. A typical category label was used for five to nine participants, and a variant category label was used for one to four participants. Internal and external auditors reviewed the data and provided feedback throughout the data analysis process. The seven domains were: (a) communication, (b) damage, (c) sense of community, (d) resources, (e) mental health support, (f) resilience, and (g) crisis plan. The cross-analysis indicated four general categories: (a) displacement, (b) structural damage, (c) teamwork, and (d) providing basic needs; 14 typical categories: (a) modes and organization of communication, (b) person to initiate communication, (c) transportation concerns, (d) staff personally affected, (e) selfless acts, (f) managing donations, (g) referral to community resources, (h) support from community, (i) variety of counseling techniques, (j) collaboration with others, (k) emotional response of students, (l) positive thinking, (m) plan in action, and (n) adjustment of crisis plan; and seven variant categories (a) school schedule, (b) overcoming diversity, (c) provided guidance to teachers, (d) provided counseling to students, (e) needs assessment, (f) student resilience, and (g) crisis plan training.

Summary and Conclusions

In summary, the findings provide current and future school mental health professionals and other education professionals within the school system a better understanding of real experiences during a natural disaster such as a flood, and specific ways to prepare and respond for future disasters. School mental health professionals may anticipate experiencing student displacement, barriers to the learning environment due to structural damage, teamwork within the school and community, and providing basic needs to students.

Sewage Overflows From the 1,000-Year Rain Event and Their Impacts on Toxic Metals in the Congaree River Watershed

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Bill Stangler, Congaree Riverkeeper
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Introduction

In October 2015, the 1,000-year rain event resulted in the release of untreated sewage into the Congaree Watershed. Following the flood, we sampled three sewage-impacted sites in the Congaree River watershed in Stoop's Creek and Crane Creek, including a wastewater treatment plant outfall, a ruptured sewage main, and a sanitary sewage overflow, as well as nearby reference sites. In surface water, we analyzed total mercury, methylmercury, 36 other metals, and carbon sources. All metals, including methylmercury, were highly enriched in the sanitary sewage overflow by a factor of 1.3 to 210 compared to reference locations. In addition, methylmercury averaged 7.2 times higher near the sanitary sewage overflow compared to other locations. Results suggested sanitary sewer overflows may be a source of metals, including methylmercury, to the Congaree Watershed.

Methodology

Between November 2015 and March 2016, our group sampled monthly at multiple locations within three sites, including Crane Creek, Gills Creek, and Stoop's Creek. A subset of sites was sampled on additional dates due to rainfall or sewage spills, totaling 12 sampling events. The Congaree Riverkeeper (Bill Stangler) accompanied our group on all sampling events.

Analyses included unfiltered and filtered (0.22 µm) total mercury and methylmercury concentrations, filtered (0.22 µm) concentrations of 36 additional metals, as well as dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), and particulate organic carbon (POC). Qualitative nanoparticle measurements were completed for 16 samples using transmission electron microscopy (TEM), and analysis of filtered metals (<3 kDa) by inductively coupled plasma mass spectrometry (ICP-MS) is underway.

Results

To determine whether sewage was a source of metals to the watershed, metals concentrations were compared between sewage sources and downstream reference locations. Compared to reference locations, the wastewater treatment plant outfall was enriched in 12 metals by a factor of 1.1 to 1.7, while the ruptured sewage main was enriched in 16 metals by a factor of 1.1 to 4.1, and the sanitary sewage overflow was enriched in all 38 metals (including mercury and methylmercury) by a factor of 1.3 to 210. The ditch, which connected the sanitary sewage flow to Crane Creek, was enriched with 21 metals by a factor of 1.1 to 32, suggesting transport through the ditch decreased metals concentrations between the sanitary sewage overflow and Crane Creek.

Time trends were compared for unfiltered total mercury and methylmercury. In Stoop's Creek, the outfall was not a source of mercury because these concentrations were lower compared to reference locations. Both total mercury and methylmercury were highest by the ruptured pipe, which was discovered by our group on February 17, and repaired within 48 hours of being discovered. Values for mercury decreased by March 30, 2016, the last sampling event.

In Crane Creek, total mercury was highest in the sanitary sewage overflow compared to the ditch and downstream reference site; however, methylmercury was highest in the ditch on December 10, before the December 31 sanitary sewage overflow. In November, the same source released >1 million gallons of raw sewage and possibly contributed to higher methylmercury concentrations in early December. Methylmercury concentrations averaged 7.2 times higher in Crane Creek compared to Stoop's Creek. Results suggested repeated sanitary sewage overflows in Crane Creek contributed to enrichments of methylmercury.

Total mercury and methylmercury (unfiltered) were positively correlated with DOC (Pearson's $r = 0.64$ and 0.52, respectively). DOC was also strongly correlated with arsenic and cadmium (Pearson's $r = 0.64$ and 0.73, respectively), as well as rare earth elements, phosphorus, vanadium and chromium (Pearson's $r > 0.67$ for all).

Summary and Conclusions

Contact with untreated sewage can cause gastrointestinal illness due to exposure to microbial pathogens, including bacteria, viruses and parasites. Untreated sewage may also be a significant source of dissolved organic carbon and toxic metals, which may impact water quality, however these processes are not well understood. Our preliminary results indicated sanitary sewage overflows were a significant source of metals, including methylmercury, to the Congaree Watershed, which should be investigated further.

Cascading Spatial Impact of Rainfall Extremes on Residents

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Introduction

The October 2015 flooding highlighted the variability in impacts from the extreme rainfall event across the state and within the Midlands. There were distinct geographic differences in flood impacts based on the location and timing of the floods. For example, some of the damage was from flash flooding in the urban watersheds, exacerbated by dam failures of impoundments that created the residential lakes throughout the Midlands counties. Other damage was related to riverine flooding. This project examined the geographic extent of the flood inundation in Richland County, residents' perception of the risks from flooding, and their behavior in response to the event itself. Combining the spatial extent of the flooding and residents' preparedness and response to the flooding helps explain the pattern and process of long-term recovery from this particular event.

Methodology

To assess the impact of the floods we first identified the areal extent of flooding based on US Geological Survey (USGS) flood inundation maps created for Lexington and Richland counties. The flood inundation surfaces were verified with field surveys conducted by the Hazards and Vulnerability Research Institute (HVRI). Using cameras affixed to cars we confirmed damage to residential structures. Data from the photos were then processed and the state of recovery was assessed for each residential parcel. Repeat visits were conducted roughly every six weeks to monitor the progression of residential recovery. The perceptions and behavior of residents in response to the event, including their recovery experiences, were gathered via a questionnaire survey using Survey Monkey from November 2015 to January 2016, with a second wave occurring from March to April 2016. A total of 290 responses were received.

Results

Two-thirds of the residents did not feel their homes could be damaged by flooding, prior to this event. For the third who did, the assessment was based on proximity (near a creek or river, knew they lived in a Federal Emergency Management Agency (FEMA) flood zone), or their mortgage company required them to carry flood insurance. Nearly 64% did not feel their property could be damaged by extreme amounts of rainfall, and 71% thought it unlikely or very unlikely that their house could be flooded by a dam failure.

In assessing damage to homes, residents stated their neighbors suffered major to total loss damages (57%) compared to the same assessment of their property (42% with major to total loss damages). Residents (20%) reported up to six inches of water, with 22% saying they had from one to two feet of water, and 24% indicating flood levels inside the home greater than four feet. About 34% of the sample reported no water inside the home. The majority of respondents had help cleaning out the flooded home, mostly from family members, friends, and volunteers.

Disaster recovery is a long, arduous process, and we asked residents where they were in the recovery timeline at the time they took the survey. The majority indicated they had removed the damaged items, applied for FEMA assistance, and filed insurance claims. Roughly 20% had applied for and received building permits and had begun construction. Most residents are using their personal savings to recover, with some additional help from FEMA disaster money, insurance, donations, and Small Business Administration loans. Half of the respondents had to move out of the home because of the damage, and when asked if they intend to rebuild and stay in the home in the future, 30% said they didn't know. The majority of residents felt it would take six months to more than a year before they could move back into their home.

Summary and Conclusions

The impacts of the October 2015 flood were geographically and temporally variable. In some neighborhoods floodwaters rose and fell quickly allowing residents to begin recovery almost immediately, while in others floodwaters lingered and uncertainty about dams delayed initiation of the recovery process. The perception of risk from flooding was low with little knowledge on risk from dam failures. Preparedness and mitigation was limited with only 29% carrying flood insurance, and 44% stating they took no precautionary actions prior to the forecasted rain event. Understanding and mitigating future flood risks, making informed decisions about development choices in flood-prone areas, and learning the lessons from this disaster will enhance our resilience to the next extreme event.

A Computational Framework for Tracking Reports, Opinions and Feelings of People in Social Media Before, During and After a Natural Disaster: Twitter Case Study in the 2015 South Carolina Flood

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Introduction

In recent years, we have been faced with a series of natural disasters, from Hurricane Katrina to the recent South Carolina flood, causing a huge amount of financial, environmental, and human losses. The unpredictable nature of disaster behaviors and damages make it hard to have a comprehensive strategic response plan. Fortunately, social media allows people to share information and opinions in the time of a disaster. This research proposes a high performance computational framework to effectively mine the patterns of people's experience, needs, and opinions. This framework could help us better evaluate the disaster management strategy in the 2015 SC floods so that we can have a better strategic plan for disaster preparedness, response, and recovery in the future.

Methodology

This research has five mains steps including data collection, data cleaning, sentiment analysis, text mining, and evaluation. This framework can be applied to any social media and disaster. The data collection is based on the frequency of related hashtags (#) or words. Several queries have been selected. This data collection is labeled based on time and date. Stopwords were removed in the second step. The third step is to get the people's feelings. Then text mining was applied on the tweets with sentiment labels in the fourth step. This step discloses the topics in tweets. Finally, we compared the results with official results.

Results

Damages from the recent flood are estimated to exceed $1 billion dollars, with 17 lives lost. There is not yet an exact set of figures in terms of people's losses and their immediate needs. In addition, few people have flood insurance policies in non-flood zones such in Columbia, SC.

This research used the information in people's comments in Twitter to get benefits in a natural disaster such as the recent flood in South Carolina. This research can help researchers to track disaster management performance in real-time to find its weaknesses and strongest performance during an unpredictable disaster. In addition, a wide range of researchers from computer science to medical domains can use the dataset and outputs.

The outputs of this project show the reasons behind people's feelings such as negative feelings during the flood and positive feeling in mid-October about "access to drinking water." This example shows that people were without drinking water in the second week of October 2015 and the problem was solved during the third week of October 2015. However, the people's negative feeling about "traffic" did not change during the research time frame.

Summary and Conclusions

The development of a computational framework can support both citizen and disaster management teams. It also creates an opportunity to share the data and discovered patterns with researchers for future possible projects. With our past expertise in analysis of structured and unstructured data, the framework developed in this proposal was able to collect, analyze, and map information from tweets for all South Carolina counties to have a better understanding about the flood effects from October 3 to October 15, 2015. By coupling sentiment analysis and text mining, the patterns of people's experience, needs and feelings were extracted. These patterns can help to both track people's needs and problems, and evaluate the performance of disaster management. The outputs of this research have benefits for different domains and can be used for future disasters.

Leveraging Social Media for Rapid Mapping of 2015 South Carolina Floods

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Introduction

Rapid flood mapping is critical for local authorities and emergency responders to quickly identify areas in need of immediate attention. One of the biggest challenges for rapid flood mapping is the limited data available during or right after the flooding event. Traditional data collection practices such as field surveying and remote sensing often fail to offer timely information for rapidly mapping the flood during or right after a flooding event. Social media platforms such as Twitter capture micro-level, real-time information using "citizens-as-sensors" during a flood, and is emerging as a new data source for disaster management and flood mapping. Despite the promising practicality, using social media data for flood assessment is relatively nascent in the literature. In this project, we proposed a novel approach to integrating social media data (tweets) with traditional data sources for rapid flood mapping, thus improving situational awareness during a flooding event.

Methodology

We first collected multiple-source data including geo-tagged Twitter data, US Geological Survey (USGS) stream gauge data, satellite imagery, and USGS inundation maps. Once the datasets were collected and pre-processed, we began by analyzing how the Twitter activity was associated with the flooding phenomena in observable spatiotemporal patterns using quantitative methods. Next, we extracted the Water Height Points (WHPs) from Twitter and stream gauge data. The WHPs serve as an estimated "ground truth" of the flooding situation at specific locations and times. Third, a kernel-based flood mapping model was developed to delineate the flooding extent. This model took three sources as input: the identified spatiotemporal patterns (used to assign the weighting parameter), WHPs, and digital elevation model (DEM). Finally, we evaluated the model by comparing the model output with the official USGS inundation map.

Results

A kernel-based flood mapping model was developed by programmatically chaining a series of ArcGIS geoprocessing tools. This model generated a flood possibility index (FPI) map with cell values normalized from 0 to 100. More than binary outputs such as flooded or not in each cell, this FPI map represents a continuous rank of estimated flooding conditions across the study area. To evaluate the FPI map, we compared it with the inundation maps produced by USGS within the study area. We can see that the dark blue areas of the FPI map generally matche the inundated areas of the inundation map within the USGS mapping boundary. While the official inundation maps were constrained within the mapping boundaries, the proposed approach provided a continuous picture of the flooding situation within the whole study area and was able to capture the flooded areas that were not mapped by the official map. For example, our model output captured the flood around the Old Mill area and Golden Hills golf course in Lexington, SC (due to the failure of the Old Mill Pond Dam) as well as less maintained rural areas of Southern Richland along the Congaree River.

However, it should be noted that whether the flood map can reflect the whole flooding situation is highly reliant on the availability of WHPs. With the proposed model, we cannot derive a good estimation of the flood situation for areas without any WHPs merely because no data is showing that area is flooded. For example, our approach did not catch the flooding in the northeast area where no WHPs were derived. One potential approach is to create a special hashtag for the social media (e.g. #scfloodmapping) right before or during a flood and encourage local residents to report flooding situation (using photos and/or text descriptions) using the designated hashtag. This approach is able to enrich the quantity as well as the quality of the WHPs.

Summary and Conclusions

Using the 2015 South Carolina floods as the study case, we developed a kernel-based flood mapping model to map the flooding possibility of a continuous spatial area based on the water height points derived from tweets and stream gauges. The identified spatiotemporal patterns of Twitter activity were used to assign the weights of flood model parameters. The feasibility and accuracy of the model were evaluated by comparing the model output with official inundation maps. The preliminary results showed that the model output provided a consistent and comparable estimation of the flood situation across the whole study area. Such a map, which can be generated in near-real time, is essential for improving the situational awareness during or right after the flooding event. This is of particular importance when social media (and/or stream gauges) is the only data available during the floods. We believe that the proposed approach provides a valuable reference for building a near-real time flood impact assessment system by leveraging social media, allowing emergency responders to make quicker and better decisions and responses with the improved situational awareness.

Scanning and Geo-Rectification of Richland County Historic Aerial Photography, 1938/39-1981

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Introduction

In October 2015, Richland County and the City of Columbia suffered historic devastating flooding along several urban streams and watersheds. Many questions will need to be resolved during the recovery and re-building process, including land use along the many watersheds and how commercial and residential land use has altered these watersheds. Digitizing and geo-rectifying the historic aerial photography will help researchers answer these questions.

With this archive, researchers have the potential to study land use and preservation theories from pre-WWII through the early 1980s. Human impacts in the photographs include: the economic and development impact of Fort Jackson, expanded suburbanization of the City of Columbia and Richland County, and land use decisions made by the expansion of the transportation systems.

Methodology

In 2001, the University Libraries scanned 2,717 aerial photographs of Richland County for the years 1938/39, 1959, 1970, and 1981. These images were scanned at 300 dpi in 24 bit TIFF format. Since 2001 the library has added the capacity to scan larger formats (12x12 and 24x24). The project scanned an additional 1,751 images of which 1,028 are of the larger format and included the years 1943, 1951, and 1966. Images were geo-rectified using ESRI's ArcGIS and ERDAS IMAGINE software systems. A critical step in the geographical rectification process is identification of ground control points. These points are objects found in every image of the same area that show the same location and/or have known geographical coordinates (latitude and longitude). Once multiple ground control points have been identified for each photograph, the software automatically rectifies the photographs.

Results

Nearly 4,000 images from 1938/39 through 1981 have been scanned, geo-rectified and added to the South Carolina Historic Aerial Photographs website available at library.sc.edu/aerialphotos. For purposes of continuity with the earlier scanning project all images were done at 300 dpi with little or no loss of detail. The addition of images from 1943, 1951, and 1966 will allow researchers to see more subtle changes in the community and fills two previously significant gaps (1938/39 to 1955 and 1959 to 1970). A significant portion of the images have a RMSE (root mean square error) of less than 2.0. Later in the fall we hope to have publicly accessible metadata available on the website. Index mosaics for Richland County aerial photography are available at library.sc.edu/digital/collections/aerials/indexes.html.

Online geo-referenced access to the imagery will benefit researchers, faculty, and students in the areas of geography, biology, environmental management and planning, civil engineering, anthropology, the law, and emergency management. Public access to the images will allow the community to participate in informed discussions on the steps needed to rebuild the City of Columbia and Richland County.

Summary and Conclusions

With this archive, researchers have the potential to study land use and preservation theories from pre-WWII through the early 1980s. Human impacts that are clearly visible and measurable in the photographs include: the economic and development impact of Fort Jackson, expanded suburbanization of the City of Columbia and Richland County to the north and east of the central city, and land use decisions made by expansion of the transportation systems in Columbia and Richland County, including the development of Columbia's interstates, US Highways, state primary and secondary arteries, which have become vital commercial links.

This project raises awareness of the historic aerial photography collections housed in the University of South Carolina Libraries and the research opportunities for students and faculty of the university and the state of South Carolina.

Collection and Analysis of Perishable Data on Failure of Earth Dams and Their Impact on Water Quality

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Introduction

Levees are constructed to protect infrastructures and crop lands from design floods, and dams are often used for flood control, and water storage for municipal, industrial, irrigation, recreation, and power-generation uses. The majority of dams and levees are composed of natural erodible materials and may fail under extreme conditions due to various mechanisms. The purpose of the study was to collect and analyze data on the embankment failures right after the historic 2015 flood in the Midlands of South Carolina. Breach dimensions were measured and soil samples were collected from selected failed or partially damaged dam sites. Laboratory and hydrologic analyses were done to characterize the breach. Water samples were collected from several dam sites and analyzed to study the ability of uncompromised and compromised impoundments to attenuate *E. coli* under different flow regimes.

Methodology

Soil samples and hydraulic data were collected for 14 embankments that failed or were damaged in the Midlands during the October 2015 flood. The investigation includes measurement of breach dimensions, collection of undisturbed soil samples, soil classification, jet erodibility tests (JET), estimation of maximum overtopping height, and calculation of maximum dam reservoir volume at the time of failure. Hydrologic analysis was also conducted for 24 dams to calculate peak discharge and unit hydrographs. Ten sets of water samples were obtained from the Gills Creek watershed; three sample sites were breached and three were at impoundments that were not breached. The remainder of the sites were inlets to the impoundments, both breached and intact. Sampling was done eight times between November 2015 and August 2016 and analyzed for *E. coli* densities.

Results

The peak discharge for the watershed for each dam was calculated using the Soil Conservation Service (SCS) method. The highest estimated peak discharge in Lexington County was at the Old Mill Pond Dam. Within Richland County, the highest predicted peak discharge was at the Lake Katherine Dam. The peak discharge, Qp, based on hydrologic calculation for Lake Katherine Dam, was found to be 2,590 cfs which was higher than the limit of the gauge located downstream.

Embankment soil type was determined using the Unified Soil Classification System. All of the studied embankments contain high proportions of sand, making them more erodible. The median size of all of the embankment material, D50, is larger than 0.18 mm. From the results of the JET test, a range of erodibility, from resistant to very erodible, is observed among the explored dams. Between kd and τc, the erodibility coefficient, kd, is considered to be the dominant parameter over the critical shear stress, τc that controls the erosion process. The soil erodibility decreases with the percentage of finer particles since the silt and clay dictate the cohesion of the soil. Based on the erodibility coefficient, kd, Upper Rocky Ford , Beaver, and Cary Lake dams have the highest erodibility, while Ulmer Pond, Old Mill, and Lower Rocky Ford dams have the lowest erodibility among the studied dams.

Urban retention ponds, e.g. lakes, do not only have a recreational use, but serve as a means of effective management practice in residential developments to control runoff during and after storm events and the associated load of bacteria limiting further downstream transport. Thus, as experienced during the recent storm event, the lack of stormwater storage volumes in the drainage network may result in elevated concentrations of bacterial pathogens in the water that represent a threat for public health. Further problems may arise from the contamination of the sediments stored in the pond, in the channel network and in the flooded areas. Surprisingly high values of *E. coli* were measured in the winter water quality samples. Samples taken during the summer were lower in *E. coli*, but still high.

Summary and Conclusions

1. From the analyses of the data from several failed/compromised earthen dams, it is found that by solely considering either the erodibility or compaction, no correlation could be observed between the breach dimensions and these parameters since the breach size depends on several factors. 2. The hydraulic load is a dominant parameter affecting the breach process. 3. A multi-variable equation is proposed to predict the breach width which takes into consideration several parameters that affect the breach process. 4. The collected data may be used to develop and validate numerical breach models and the proposed relations may be used to predict breach dimensions. 5. While there is some evidence that the intact impoundments reduced E. coli densities, this was not conclusive due to significant sources of *E. coli* entering the impoundments locally.

Collection of Perishable Data From Failed Culverts During the October 2015 Historic Flood Event

Sarah L. Gassman, Inthuorn Sasanakul, Charles E. Pierce, William Ovalle, Ryan Starcher, Emad Gheibi and Mostaqur Rahman, Department of Civil and Environmental Engineering

Introduction

South Carolina recently experienced a historic rainfall event that caused catastrophic flooding and crippled the transportation infrastructure. Initially, almost 400 roadways were closed due to flooding, a majority of which were closed from roadway washouts. Many of these roadway washouts resulted from failure of the pipe culvert soil system beneath the roadway. The culvert infrastructure is critical to not only preventing flooding during normal and extreme conditions but is integral to proper road and highway maintenance. This report summarizes a post-flood reconnaissance study aimed to collect perishable data from sites where pipe culverts failed and roadways were washed out. The study included collection of extensive photographic evidence and documentation of descriptive information related to the failure, collection of soil samples, and field and laboratory geotechnical tests.

Methodology

Field Reconnaissance: Visual inspection was performed to obtain extensive photographic evidence and document descriptive information related to the culvert failures, including: 1. soil erosion around the pipe; 2. physical conditions of the pipe; and 3. evidence of slope failure or scouring. Field measurements included: 1. cross-sectional area and slope of failed channel; 2. lateral displacement and settlement of soil; 3. culvert material, size, and shape; 4. locations of the failure on the pipe; and 5. geometric relation between the culvert cross-section and the channel cross-section.

Soil Collection: Bulk and core samples of soil were collected from the embankment and foundation when possible. Soil collection was performed in accordance with ASTM D-1587 and ASTM D-1452. Disturbed, bulk samples were obtained with a hand auger. Undisturbed samples were collected using Shelby tubes.

Laboratory Testing: Laboratory testing was performed to characterize the geotechnical properties of the field samples. Sieve and hydrometer analyses were conducted in accordance with ASTM D-422. Atterberg limits testing was conducted in accordance with ASTM D-4318. Each soil was classified using the Unified Soil Classification System (USCS) according to ASTM D-2487. Permeability testing was conducted using a Shelby tube permeameter in accordance with ASTM D-2434. The unconfined compression test was performed in accordance with ASTM D-2166.

Results

About two weeks after the flood event, 138 of the initial 400 closed roads were still closed; a majority of these due to roadway washouts. In Richland and Lexington Counties there were 65 road closure sites and at least 15 of these were closed due to failure of the pipe culvert soil system beneath the roadway. Many of these sites were scheduled for repair and were reopened by the end of November 2015. Given this time constraint, the research team was able to conduct field reconnaissance and obtain photographic evidence at 22 roadway sites, nine of which were already repaired or being repaired. From these sites, three sites were selected for full field investigation based on the accessibility and feasibility to collect meaningful data. At all three sites, there was evidence that these roadways had been overtopped by the floodwaters. Two of the three sites were involved with a washout of road embankment and culvert. The third site was partially damaged and it was found that the roadway embankment also served as a dam for a shallow pond having an approximate surface area of 2.5 acres. Over 26 bulk samples and 15 undisturbed samples were collected from these sites for laboratory testing. The embankment materials were found to be clayey sand or silty sand with fines contents ranging from 10% to 40%. The permeability was found to range from 10-3 to 10-6 cm/s. Soils were found to range in consistency from soft to stiff (i.e., poor to excellent material for embankment construction).

In addition to the photographic evidence collected directly by the research team, data collected by SC Department of Transportation (SC DOT) personnel at the 65 road closure sites in Richland and Lexington Counties was reviewed and compiled as part of this project. This data included photographic evidence taken from the failure sites in the days following the flooding and a preliminary damage assessment report for each site.

Summary and Conclusions

Perishable data was collected from sites in Richland and Lexington counties where damages or failures occurred to roadways during the October 2015 historic flood in South Carolina. Data includes photographic evidence and descriptive information related to the failure at 65 sites, and collection of soil samples and field and laboratory geotechnical testing at three sites. These data serve as valuable sets of well-documented case histories needed to support future research studies for advancing our fundamental understanding of complex failure mechanisms in extreme scenarios.

This project provided an opportunity for four graduate students and 15 undergraduate students to gain field and laboratory experience, build team working skills and apply technical knowledge while working on real-world natural hazards research.

Collection of Perishable Data From Failed Dams During the October 2015 Historic Flood Event

Inthuorn Sasanakul, Sarah L. Gassman, Charles E. Pierce, William Ovalle, Ryan Starcher, Emad Gheibi and Mostaqur Rahman, Department of Civil and Environmental Engineering

Introduction

A large storm event over five days from October 1-5, 2015, produced over 20 inches of precipitation in some locations. This historic storm event caused extreme flooding and failures of critical geotechnical infrastructure across South Carolina, including many dams and roads. The goal of this study was to compile perishable data from dams that failed during the extreme flooding in Columbia, South Carolina. These data serve as valuable, well-documented case histories needed to support future research studies for advancing our fundamental understanding of complex failure mechanisms in extreme scenarios.

Methodology

Field Reconnaissance: Visual inspection was performed to obtain extensive photographic evidence and document descriptive information related to failure. Field measurements were performed to collect perishable data such as width of the breach, displacement/settlement information of the dam and foundation soil, and embankment dimensions.

Soil Collection: Bulk and core samples of soil were collected from the embankment and foundation when possible. Soil collection was performed in accordance with ASTM D-1587 and ASTM D-1452. Disturbed, bulk samples were obtained with a hand auger. Undisturbed samples were collected using Shelby tubes.

Laboratory Testing: Laboratory testing was performed to characterize the geotechnical properties of the field samples. Sieve and hydrometer analyses were conducted in accordance with ASTM D-422. Atterberg limits testing was conducted in accordance with ASTM D-4318. Each soil was classified using the Unified Soil Classification System (USCS) according to ASTM D-2487. Permeability testing was conducted using a Shelby tube permeameter in accordance with ASTM D-2434. The unconfined compression test was performed in accordance with ASTM D-2166.

Results

During and following the storm event, a total of 47 dams breached, with 22 located in the Columbia area. The selection of dams where full field investigation would be performed was based on the accessibility and feasibility to collect meaningful data. Collection of soil samples and laboratory testing was performed at nine dam sites and over 100 bulk samples and 35 undisturbed soil samples were collected. Data collection for each site included dam age, storage capacity, dam geometry before failure, breach location and dimensions, photographic evidence and descriptive information related to the failure, vegetation density, spillway type and conditions, and geotechnical soil properties.

For the nine dam sites investigated in this study:
1. Seven were breached and two were heavily damaged.
2. Their ages range from 60 to over 100 years.
3. Dimensions range from 12 to 26 ft in height and 260 to 1400 ft in length.
4. The average slope of the dam embankments was approximately 20-30 degrees for all except two dam sites, with slopes of 50-65 degrees.
5. Four serve as roadway embankments.
6. Three were located close to a major road, and dam failure possibly caused downstream road damage and washout.
7. Six showed evidence of overtopping.

Failure of these dams most likely initiated from the surface erosion of the downstream embankment causing loss of stability. Internal erosion is a probable cause of failure for three dams because no evidence of surface erosion was observed and eyewitness accounts noted that overtopping did not occur. Results of laboratory testing showed that most of the dam materials were sands with various amounts of fines. Some of these dams had soils with fines contents as low as a few percent, thus were highly susceptible to internal erosion. Several dams had a layer of organic topsoil with relatively low permeability covering the surface of the dam while the main dam structure was made of sands, or silt or clay sand mixtures. Many were covered with dense vegetation including large mature trees. The penetration of tree roots through dam was observed at the breach area of three dam sites. The research team inspected the spillway and/or drainage system for each dam. More than half of the dams investigated breached near the spillway structure and/or drainage system. The condition of these systems prior to failure was unknown. All of the dams investigated appear to be homogeneous earth fill dams and have no definable core or filter zone, however soil samples collected at each dam were limited.

Summary and Conclusions

Perishable data was collected from sites in Richland and Lexington counties where damages or failures occurred to dams during the October 2015 historic flood in South Carolina. Field evidence suggested that the majority of dams investigated were overtopped. Most of the dams were constructed with sand having ranges of fines content. Many dams were covered by dense vegetation. To date, only one dam site has been repaired. Lack of repair to the majority of the dams has resulted in long-term impacts to the affected communities.

This project provided an opportunity for four graduate students and 15 undergraduate students to gain field and laboratory experience, build team working skills and apply technical knowledge while working on real-world natural hazards research.

Rapid Assessment of Bridge Scouring Following Extreme Flood Events

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Introduction

One of the most common causes of bridge failures in the United States is scouring, defined as the erosion of riverbed or bank material from bridge foundations due to flowing water. In addition to regular and annual flooding, extreme conditions like those experienced in South Carolina during October 2-5, 2015, can have significant effects on scouring. Despite the existing engineering formulations, a full understanding of how pier scouring fluctuates with flow changes is still lacking. The development of scour modeling requires monitoring of scouring processes. During high intensity flow events, the flow-structure interaction results in a variety of vortices and dynamic bed shear stresses which erode bridge foundations and can lead to structure instabilities. The objective of this study is to develop systems for the in situ collection of bridge scouring data that can be used for improving theory and modeling of bridge scouring processes for a variety of flow regimes.

Methodology

We developed state-of-the art technology to allow visual and quantitative inspection of bridge scouring using remote acoustic and optical techniques, providing data with a large spatial variability. Our methodology increases the certainty in identifying scour depth and lateral extent. In particular, as part of this work we developed an autonomous surface vehicle (ASV) equipped with a high resolution side-scan sonar (450MHz) for assessing the spatial extent of scouring in bridges and a high precision acoustic sensor (200KHz) for accurate measurements of absolute scour depths. The vehicle is equipped with global positioning system (GPS) for navigation and a scanning rotating Laser system (LiDAR) for 3-D mapping of above-water structures. It is fully automated and ensures rapid deployment without the operator being in the water, which is ideal for situations with potential for exposure to dangerous conditions.

Results

USC's ASV platform is built off the MOKAI® kayak. The vehicle is approximately 3.3m long and is powered by a 7 HP 4-stroke Subaru engine allowing for speeds up to 5.5m/s. The vehicle uses an impeller jet drive that allows safe navigation in shallow water in the presence of debris without posing any danger to aquatic life. The vehicle's throttle and steering servos are integrated with a Pixhawk flight controller, similar to that used for drone control and navigation. The Pixhawk controller can be used for manual operation by a radio transmitter or as an autopilot following predefined survey lines, using the open source software Mission Planner for programming survey missions in autonomous applications. The scientific equipment is connected to an onboard computer controlled with remote desktop software via mobile Wi-Fi. A 900MHz data radio with a range up to 10 miles is used to continuously transmit vehicle status information to the base station.

We have performed surveys of five sites, two of which (Cooper and Wando rivers over I-95) were in cooperation with the SC Department of Transportation (SC DOT). Four of the five sites involved bridge piers. The Congaree - Gervais Street site survey involved mapping the extent of the sand deposit introduced by the collapse of the Columbia Canal. At the time of the survey the sand deposit had elongated to 150 meters downstream following the left bank of the river. The four sites, all involving rectangular bridge piers, showed evidence of scouring with lateral extents varying from 8 meters (Wateree - US378) to 30 meters (Cooper - I-526). Typically scour footprints resemble a symmetric wake-like form aligned with the flow and structure. Among the sites surveyed, the scour footprints were found to be on a range of slightly asymmetric to largely one-sided across the long axis of the pier oriented with the flow. A large area of the scour footprint was located along the pier sides, extending laterally and downstream of the pier. Maximum scour depths occurred in the vicinity of the pier face and upstream sides, measuring from one to four meters.

Summary and Conclusions

We developed an autonomous vehicle capable of assessing both the lateral and vertical extent of pier scouring. It can be deployed quickly and safely under flooding conditions. The ASV replaces liability and cost that comes with placing a life in the water and improves the efficiency of surveying larger bridge sites. Applications of the vehicle can be expanded beyond scour studies through the addition of instrumentation.

Additional surveys are planned in cooperation with the SC DOT and US Geological Survey (USGS) to improve infrastructure maintenance and the science behind bridge scouring. As part of this collaboration, a fixed station to be set up by USGS and funded by SC DOT will be augmented with additional equipment provided by USC. The duration of the deployment will be one year, providing valuable time-series bridge scouring data for a wide spectrum of flows.

Creative Responsiveness: Connecting Stories of Resiliency in Crisis

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Introduction

What role do the arts play in helping a community come to terms with trauma such as natural disasters? In South Carolina we experienced a devastating event in October 2015. Eleven trillion gallons of water flooded our streets, destroyed dams and devastated families. In the flood's wake we are left with compelling stories of heartbreak, loss, bravery, service, deception, and resilience. Researchers created interdisciplinary arts-based approaches to capture ethnographic data and co-construct these stories into a piece of theatre. Over 30 semi-structured interviews, and an analysis of first-hand social media accounts were utilized to create the ethnodrama, "And the Flood Goes On... a play about the human impacts of disaster." The verbatim stories in the play confront issues of trust, community, resilience and how we serve those at the margins of our communities.

Methodology

The researchers conducted 25 semi-structured qualitative interviews with people who experienced the flood as victims, volunteers or first responders. The interviews were coded and themes were established across the interviews. Additionally, discourse and narrative analyses were applied to social media and news platforms as a means to gather additional anecdotal accounts of the flood. The ethnographic play-building process was also an important methodology. The actors participating in the reading provided feedback to the initial draft of the script (which was comprised of verbatim text from the interviews) and shared their own stories of the flood. Their stories became data and were added to the subsequent drafts in which we created six fictional, composite characters (to protect the anonymity of the interviewees). Further data will be collected during post-show discussions.

Results

The ethnodrama, "And the Flood Goes On," is the culmination of 11 months of analyzed data storying the human cost of the 2015 South Carolina flood. The play sets October's devastation into a larger context – a six-month period in which South Carolina faced itself through a series of unspeakable and difficult events. It is hard to know through qualitative data whether the shooting of Walter Scott or the murder of nine brave souls at Mother Emanuel church or the removal of the Confederate flag impacted how residents responded as a state and a community to the October floodwaters. That question, however, was on the minds of many residents as they shared their own stories of heroism and selflessness, community and connection.

An important theme highlighted from the interviews described a need for an organized and immediate communication infrastructure in the city. People in need did not know whom to contact; people seeking how to help did not know where to go; and supply centers did not have a centralized way to match their supplies with people's specific needs.

Another powerful theme reflected how recipients of help felt "silenced by gratitude." People were simultaneously grateful for aid, and yet did not have a way to communicate their frustration about how help was administered. Teams of volunteers came to tear down drywall and clear out houses. That was welcomed and much needed assistance, yet, in that process, possessions were thrown away leaving feelings of "my life was disregarded as junk."

Interviewees shared how the flood is still an experience in the present tense. Others admitted how, at this one-year anniversary, volunteer fatigue has set in making it hard to find the motivation to help and serve areas still in desperate need.

The results of the interviews and community art-making efforts reveal the deep personal, financial, and heart-breaking reality of the flood on many Columbia residents. The research also revealed the tremendous heart of the community. It shows how fraught concepts such as resilience and gratitude are and offers insights into possible suggestions for how to handle future emergencies.

Summary and Conclusions

This project studied the human costs of the 2015 floods as well as what role the arts play in discussing trauma and loss after a natural disaster. Eleven trillion gallons of water flooded South Carolina streets in 2015, destroyed dams and devastated families. In the flood's wake researchers gather stories of what was left after the floodwaters receded. Researchers found stories of heartbreak, loss, bravery, service, and resilience and represented the ethnographic data as a piece of theatre. Over 20 semi-structured interviews, and an analysis of first-hand social media accounts were utilized to create the ethnodrama, "And the Flood Goes On... a play about the human impacts of disaster." The verbatim stories in the play confront how we serve those at the center and margins of our communities and offers insights for future traumatic events.

Leveraging Perishable Impact Data Into Long-Term Recovery Forecasting

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Nathan Huynh, Department of Civil and Environmental Engineering

Introduction

Long-term recovery from disasters is one of the least understood elements within the disaster cycle. While some neighborhoods and communities are able to rebuild and recover quickly, others languish, sometimes failing to recover to what was there before. This project seeks to address some of the data needs associated with empirically measuring and modeling disaster recovery outcomes and processes driving them. Specifically, the objective is to collect perishable post-event data on populations, impacts, and recovery that can be input into a model that predicts when, where, and why some households in Columbia, SC recover and some do not.

Methodology

Impacted communities around Columbia, SC provide the research team with an invaluable test bed where we have direct access to data and will be able to conveniently track recovery. We must collect perishable data related to the flood damage levels and infrastructure restoration immediately in order for the team to utilize these communities as a test bed. The team focused on assessing impacts and damages by collecting perishable data on damage to households, risk and recovery perception, and neighborhood impacts, including damage levels, infrastructure restoration information, individual household impacts, and neighborhood influences on recovery.

Results

Long-term recovery data collection continues although the project has officially ended. Preliminary analysis of impact and damage information at the address level from the National Flood Insurance Program (NFIP), the US Small Business Administration (SBA), and the Federal Emergency Management Agency (FEMA) shows a systematic under-valuation of damage by FEMA when compared to damage information from both SBA and NFIP. Analysis of the specific drivers of recovery at the neighborhood level continues to produce varied results, indicating a distinct recovery divide and a deepening gap between affluent and marginalized residential areas.

Summary and Conclusions

Recovery is a long process, one that cannot be easily and quickly captured over a short time span. Preliminary analysis of data indicates a recovery divide across the study area, likely associated with ready access to capital, social network connections, and federal government support for those who were eligible. Low (preliminary) federal indication of damage from the event made federal support for recovery for many already disadvantaged populations unavailable. Social vulnerability, a measure of pre-event socio-demographic conditions will also likely play a role in the recovery process. This pre-event condition, coupled with the historic ineligibility rates found in this disaster will have a profound effect on the recovery trajectories for many marginalized communities across the state, but especially in Georgetown, Williamsburg, and other hard-hit communities in east-central portions of the state. However, support from the Central Carolina Community Foundation's One SC Fund did not focus solely on impact but rather on the pre-event vulnerability of communities, resulting in much non-profit work in the hardest hit and most vulnerable areas of the state.

The Value of Public Libraries During a Major Flood: What the 2015 Catastrophic Flooding in South Carolina has Taught Us

Samantha Kelly Hastings, Jingjing Liu and Feili Tu-Keefner, School of Library and Information Science

Introduction

In October 2015, several counties in South Carolina experienced catastrophic flooding that caused severe damage, including loss of residential homes and other calamities. This study investigates public libraries' value to their communities, especially to vulnerable populations, and their legitimacy as partners of public health agencies during and after a disaster. The focus of the research includes various aspects of information, technology, and user support. A framework for communication preparedness and implementation recommended by public health experts is used to examine the role of public libraries during the catastrophic flooding (between October 4-10, 2015) in Richland County and Orangeburg County. The targeted public libraries are the Richland Library, the Orangeburg County Library, and the South Carolina State Library. We examine the situation-specific information dissemination, resources distributed and used, and services provided by public libraries and librarians, as well as the social media applications for communication during and after the disaster.

Methodology

The methodology used was qualitative and survey-based. Focus-group meetings with public library administrators and librarians were used to examine how librarians responded during this time. The discussions centered on the use of resources to provide information services as well as on users' information needs and technology access during and after the disaster. One-on-one interviews with community members who were affected by flooding in the target areas were conducted to investigate their information needs and technology access. Community members who were affected by flooding in the target areas were the potential subjects for this component of the study. We are still conducting interviews with community members. An in-depth interview with a Federal Emergency Management Agency (FEMA) agent was held to identify issues regarding the technology ability needed to file damage claims. Additionally, a survey was also conducted to explore library patrons' use of social media during the flood.

Results

We have completed the focus-group meetings with public library administrators and librarians, the interview with a FEMA agent, and the survey. However, one-on-one interviews with community members are still ongoing. One of the research purposes is the investigation of public libraries' value to their communities and their legitimacy as partners of public health agencies during and after a disaster. The Richland Library administrators and librarians worked with the offices of State Senator Lourie and U.S. Congressman Clyburn to help get FEMA to the local communities and created "disaster recovery centers for FEMA." In fact, "14% of all FEMA applications" were filed at the Richland Library's main and branch libraries. The Richland Library was a water distribution site; librarians took books, toys, and computers to shelters. This successful collaboration with public health agencies shows the value of public libraries in facilitating emergency response and recovery during this disaster.

Our research also examines how librarians use technology (including social media) to provide situation-specific information and services. Preliminary results reveal that technology access was crucial to obtaining credible information and disseminating resources and services to the community. The results of the survey echo these findings. The internet was predominantly used by librarians to gather and distribute resources to community members. Librarians used social media sites to answer patrons' questions with an average nine-minute response time. On the Richland Library's Facebook site, the library's posts "were shared 1,386 times, an average of 98 shares for each post." From October 4-12, the library's Twitter account "gained 242 new followers."

However, our findings also show that a discrepancy exists between the reliable resources vital to consumers and the health information shared with them by the public libraries. Public librarians were not fully prepared to provide sufficient essential disaster and health information for adult users, especially through an online venue, before and after the natural disasters hit South Carolina. Information and technology literacy issues created barriers for many community members in accessing FEMA applications and filing claims online.

Summary and Conclusions

In conclusion, this research underscores how well positioned the information studies are to investigate community development and engagement. Library and information science researchers are taking social responsibility, through their research, to help local communities examine all aspects of community phenomena. The 2015 catastrophic flooding in South Carolina provides such a platform. The results of the study will be presented to local and statewide public library personnel to aid in their creation of disaster and health information digital resources online, community-engaged programs, and user-centered outreach services. In addition, the results will serve as baseline data for the development of a theoretical framework for advanced investigations in the future.

Contexts of Recovery: Investigating Patterns of Coping and Support

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Introduction

A limited amount information is known about how communities can respond effectively to support longer-term social aspects of recovery. While disaster preparedness for crisis responses have improved, recovery processes are relatively understudied.

The overarching question guiding this inquiry is how neighborhood and patterns of community-based support are associated with mental health outcomes. We are focused on how recovery and resilience develop in the context of community resources and relationships. It is hypothesized that (a) a perceived supportive neighborhood social climate and (b) community-based resources will mediate the relationships between persons' experience of stressors and indices of their affect and health.

Methodology

We contacted persons from different communities affected by the flooding (e.g., Lower Richland, Forest Acres, and South Beltline) to invite them to participate in the study. We partnered with non-profit organizations working on recovery efforts, local recovery organizing committees, community forum, religious organizations, and neighborhood organizations. Data collection will continue to the anniversary of the flooding.

We conducted surveys and interviews using the same protocol to offer potential participants the modality that better suited their availability and preferences. The pilot study uses a comparative design grouped by community. Data was collected 8-12 months after the flooding event.

Results

This flooding event was unusual in that communities with different histories, socio-economic status, racial and ethnic demographics, and rural-urban organization were affected in similar ways. However, these communities create unique contexts for recovery efforts. By comparing patterns of support, difficulties faced by residents, and the resources available for addressing challenges of recovery in these particular communities, we can learn more about limits and promise of recovery efforts and the resilience of individuals and their communities

Results from preliminary data will be presented at the conference as data collection is ongoing.

The domains of the protocol focused on personal demographics, residential history and satisfaction. Measures to assess the neighborhood environment focused on relationship with neighbors, neighborhood quality, and social climate. Broader community experiences with transportation and capacity for responding to needs of residents was included to capture practical aspects of recovery challenges and resources. The protocol inquired about different forms of interpersonal support and social connectedness to understand how research participants coped with stress and health problems. Finally, we closed by asking participants about their hopes for the future and their subjective well-being.

Summary and Conclusions

We view this initiative as a unique opportunity to provide information to residents and leaders of recovery efforts about how components of their intervention may have helped those displaced by the flooding and consider needs that still need to be addressed.

Scientifically, we expect the findings to inform social sciences and health fields about the importance of environmental factors in recovery and resilience. Locally, we expect the findings and the collaborative research process to identify needs and provide opportunities to raise awareness and engage in civic action to address those needs.

Resilience in the Wake of the Historic Flooding of South Carolina: Collaboration, Communication, and Community

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Introduction

The catastrophic 2015 flooding of Columbia, South Carolina yielded significant loss of life and property in a region already rife with economic, health, and educational disparities. Yet the community response to the disaster was overwhelmingly positive. In shifting from a vulnerability/hazards model to a model of resilience, the current study sought to identify characteristics of community resilience that enabled residents, organizations, and local government to overcome the challenges of the floods and meet the needs of affected community members.

Methodology

Individuals from five key community stakeholder groups were recruited to participate in a qualitative study on community resilience. Researchers completed in-depth, semi-structured interviews with 39 individuals from five groups impacted by flooding: local residents, government officials, community leaders, first responders, and journalists. Participants reported on their personal and professional experiences related to the flooding, including preparation and awareness of risk prior to the flooding, immediate responses to the disaster, and post-flood recovery and rebuilding efforts. Qualitative analysis was used to identify common themes and characteristics of community resilience that were critical for survival and recovery.

Results

Across five key community stakeholder groups, participants recognized the critical role of the community in preparing for, enduring, and recovering from disaster. Participants were asked to think about their awareness of risk for flooding and specific preparations that were made. Stakeholders agreed that the unique nature of the October 2015 flooding contributed to difficulties in being prepared for the event, both for individuals and in terms of the larger community response. Stakeholders commonly reported that residents of Richland County failed to recognize the potential impact of widespread dam failure. Participants also frequently discussed that natural disaster preparation is largely focused on hurricanes in South Carolina, and this contributed to lack of awareness and poor preparation for a widespread flood (rather than wind) event. Most residents reported little preparation for the flooding and a sense of invulnerability that was shattered as flood waters rose. Residents who were impacted frequently cited their lack of knowledge of local geography (i.e., connectedness of water systems, proximity to dams and creeks) as a barrier to recognizing flood risk. A number of key themes emerged when participants described their experience of the flooding. Residents overwhelmingly cited the local community response as most critical during the actual flood event. Residents described "grassroots" rescue efforts as key; while several government officials and first responders reported that preexisting infrastructure problems (i.e., poor roads/bridges), lack of resources (i.e., no rescue boats), and an out-of-sync county/city management system hampered immediate efforts to respond as floodwaters rose. All groups cited the critical role of social media in communicating life-saving information to residents, first responders, and community rescuers during the event. Stakeholders expressed hope for recovery but cited lack of information, limited financial resources, existing inequalities, and lengthy timelines as challenges in rebuilding efforts.

Summary and Conclusions

The 2015 flooding posed significant challenges for South Carolina residents and communities, many of whom are still in early stages of rebuilding. Despite facing multiple adversities, those who were impacted remain largely hopeful that stronger systems can emerge in the wake of the disaster. Building more resilient communities requires that residents, government agencies, and community organizations partner together to meet the diverse set of needs that emerges when unforeseen disaster occurs. Ongoing awareness and a commitment to rebuilding are necessary to ensure that residents feel supported in their recovery efforts. Key aspects of community resilience that emerged from the study included community awareness of risk, effective communication, strong community partnerships, and a shared hope for the future.

River Gauge Estimation

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Introduction

Flooding in Cedar Creek and the Congaree River floodplain damaged a critical US Geological Survey (USGS) stream gauge on Cedar Creek in Congaree National Park. We reconstructed missing data from that gauge using USGS data from intact gauges. By building functional data analysis models between the damaged gauge and an intact gauge based on significant flood events since the 1990s, we are able to estimate the missing information from the damaged gauge. These estimates will be a useful resource for both researchers and policy stakeholders.

Methodology

USGS-Water Resources Division 15-minute interval data for stream gauges was used to initially construct data sets of high stage/flows in which all gauges were operable; functional relationships between those gauges were used to predict flows for the inoperable gauges in the October 2015 flood event. The stage measurements for both the Congaree and Cedar Creek gauges were completely available for seven flood events previous to the October 2015 event. Stage heights were captured every hour over a period of two to three weeks, depending on the length of the flood event. Because of the high-throughput nature of the observed data, we chose to treat the observations as functional data, so that each stage-height trajectory for each gauge could be modeled by a continuous function for each flood event.

Results

To determine the relationship between the two gauges, we used functional regression modeling (Ramsay and Silverman, 2005). The Congaree stage trajectories played the role of predictor functions, while the Cedar Creek stage trajectories were response functions whose values could be explained or predicted using the Congaree functions. We used a smoothing spline approach to represent the stage functions, using spline functions to best fit mathematical curves for the observed measurements while enforcing some smoothness conditions. We used a concurrent functional linear model (Ramsay, Hooker, and Graves, 2009) that used both the sampled Congaree stage functions and their derivative functions to estimate the model coefficients at a fine grid of time points (500 per flood event).

The eventual model we selected was a functional regression that included an interaction between the Congaree stage function and the derivative function. This allowed the effect of the Congaree stage to vary depending on the rate of change of its stage height, thus capturing important hydrological features such as overbank flow. The model predicted the variation in the seven sampled Cedar Creek stage functions very well. We used the model to predict the unknown Cedar Creek stage height function for the October 2015 flood event. Our model predicts a maximum Cedar Creek stage height of approximately 15 feet during October 2015, which is as high or higher than the Cedar Creek maxima of the other seven flood events in recent years. We derived bootstrap prediction intervals to estimate the uncertainty in our predictions.

A limitation of our methodology is that the curve predictions were sensitive to the amount of smoothing applied to the spline representations of the functions. Further research is needed to obtain methods of choosing good values of the smoothing parameters automatically.

Summary and Conclusions

Congaree National Park personnel need a precise estimate of the peak stage on the Cedar Creek gauge at Weston Lake to guide management policy on infrastructure location and design, native species, invasive species, visitor safety, water quality, and numerous other management decisions. A variety of researchers use the Cedar Creek gauge to study hydrology, fluvial geomorphology, sediment deposition, soil nutrients, water quality, forest succession, fish and invertebrate ecology, and other scientific endeavors.

Our use of a functional regression model allows intricate details of the stage function values and rates of change to predict stage heights at Cedar Creek (the downstream gauge). The model displays strong in-sample predictive accuracy. More research is needed to measure out-of-sample accuracy and uncertainty in prediction and choose smoothing parameters.

Mapping River Erosion and Geomorphic Change Caused by an Extreme Flood

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Introduction

This project had two goals: 1. measure geomorphic changes caused by the 2015 South Carolina floods, and 2. test the feasibility of using new technologies to develop large-scale topographic data to map river channel and floodplain changes. The importance of extreme floods to changing rivers is a long-standing question in fluvial geomorphology. This study examined erosion and sedimentation caused by the October floods along the Congaree River and tributaries. It found that broad-scale patterns were largely determined by rainfall intensities on the tributaries, whereas much of the erosion resulted from localized phenomena such as dam failures and structures. Large-scale topographic data was produced by the combined use of an unmanned aerial vehicle (UAV) to collect aerial photography and structure from motion (SfM) photogrammetric software to produce spatial models.

Methodology

Erosion and sedimentation were measured by field reconnaissance, topographic surveys, and aerial photographs collected with a UAV. Early field work measured thin sediment deposits and located erosion sites for later surveys. Precise locations of ground control points (GCP) for rectifying aerial imagery were made with a dual-band X900S-OPUS GNSS (GPS with sub-cm potential) and total station. Due to uncertainties about UAV Federal Aviation Administration registration, helium balloons were used initially to obtain imagery, but this was expensive and inflexible. A Phantom 3 Professional quadcopter was acquired in February 2016 and proved efficient at acquiring high-resolution imagery. Photoscan SfM software was installed on a Geography Department server, and used to align overlapping images, recognize common points, and build cm-scale point clouds, orthophotographs, and digital elevation models (DEMs).

Results

Field work indicated several sedimentation sites on the Congaree River, Gills Creek, and other tributaries that enter the Congaree from Richland County. Theories that spatial patterns of erosion and sedimentation would be related to stream power were abandoned because local features and conditions largely dominated loci of geomorphic change. For example, sediment tended to be deposited below sources or on sites that encouraged deposition. Similarly, erosion tended to occur where human structures disrupted hydraulic conditions. For example, a large scour hole formed in the floodplain on the east side of the Congaree River just beyond the end of the levees where flows spread out from the main channel. Erosion in Gills Creek was largely concentrated in local areas experiencing high shear stresses. Thus, the scale of this study shifted away from broad patterns of geomorphic change governed by stream power; i.e. functions of drainage area. Instead, it shifted to documenting local-scale erosion at specific sites and developing mapping techniques to document geomorphic change at this scale.

Aerial imagery collected by UAV consisted of more than 60 photographs at each of three sites. DEMs generated by the Photoscan software at each site were loaded into ArcMap, a geographic information system (GIS) which allowed generation of contours, shaded relief maps, and other visualizations of the high-resolution data. Geomorphic change detection was conducted by differencing 2016 Photoscan UAV DEMs with pre-flood DEMs derived from light detection and ranging (LiDAR) topographic data flown for Richland County circa 2010. Preliminary results indicate that the UAV data are at a much higher spatial resolution than the LiDAR data, provide superior imagery away from vegetation, and can be used to detect differences between pre- and post-flood surfaces. Under heavy vegetation canopy, however, obtaining continuous topographic surfaces with UAV proved difficult, so blurred patches occur where vegetation was thick. It is hoped that this effect can be minimized by reflying the sites during the leaf-off winter period.

Summary and Conclusions

At broad geographic scales, the ability to scientifically predict erosion and sedimentation by large floods a priori has been limited due to a theoretical void. The South Carolina floods presented an opportunity to examine geomorphic impacts. This study focused on methods for creating detailed, large-scale maps using new technologies that enable relatively rapid, inexpensive acquisition of high-resolution topographic data. The use of UAV in conjunction with SfM photogrammetric post-processing proved highly effective in generating large-scale topographic maps suitable for geomorphic change detection except under dense vegetation. Future work will explore the potential for repeat flights to detect changes between flights and determine if UAV point-cloud data can be merged with airborne LiDAR point-cloud data to improve topographic maps.

Nonstationary Intensity-Duration-Frequency Curves for Drainage Infrastructure Coping With the October 2015 Catastrophic Floods in South Carolina

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Introduction

Climate change increases the amount of water in the atmosphere and probable maximum precipitation (PMP). Studies have shown the frequency of changes relates to atmospheric oscillations (e.g., El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO)). Engineers use intensity-duration-frequency (IDF) curves to design infrastructure that controls the risk of flooding. IDF curves are computed based on the assumption the occurrence probability of rainfall is not expected to change over time (stationary concept). However, studies demonstrated precipitation extremes show nonstationary behaviors and the stationary concept is not valid. This study examined Extreme Value Analysis (EVA) using stationarity (H0; no trends) and nonstationarity (H1; trends in data) hypotheses.

Methodology

Available water year data for intense rainfall and floods were extracted at 225 climatic and four hydrometric stations for different durations. The resulting data were correlated with large scale features using Principle Component Analysis (PCA) and incorporated in K-mean and hierarchical clustering algorithms to perform a clustering analysis.Various EVA distributions, including the generalized extreme value (GEV), Generalized Pareto (GP), and Point Process (PP) functions, were tested for nonstationarity by incorporating PDO, ENSO and intense rainfall associated with daily floods as covariates. Results obtained with a stationary model without trend in the location, scale, and shape parameters were compared with results from a nonstationary model with trend in at least one of those parameters. The parameters were estimated using MLE, GMLE, Bayesian, and L-moments.

Results

PCA analyses showed strong correlation between intense rainfall and floods with PDO and ENSO. Clustering algorithms classified the study region into seven clusters. Extreme analysis was performed for each cluster. Two nested stationary versus non-stationary EVA models were fitted to short- (1-hour) and long-duration (seasonal) intense rainfalls and flash floods by incorporating PDO and ENSO as covariates. In most cases, the GEV and the GP models with the upper bounded Weibull (light-tailed) and Frechet (heavy-tailed) distributions showed the best fit to the estimated parameters. Maximum seasonal intense rainfalls and floods responded to ENSO and PDO while sub-daily intense rainfall modulates corresponded to 5- to 11-day floods. In both cases, the p-value from the likelihood ratio test was less than 0.05 indicating incorporation of the selected covariates for all parameters is statistically significant and the null hypothesis (stationarity) should be rejected. Further, the return level plot (e.g., 2- to 1000-year) with 95% normal approximation confidence interval computed by Monte Carlo algorithm for both intense rainfall and floods was much lower than those under nonstationary assumption. Computed 24-hour design storms for all return periods are much larger than South Carolina Department of Transportation (SC DOT) IDF curves. For example, the 24-hour storm (8.3”) in urban Columbia, SC is recurrent at a 20% probability (20-year) while the same value is recurrent at a 99% probability (100-year) in SC DOT 24-hour design IDF curves. As another example, the 24-hr storm (8.6”) in a rural Saluda County drainage system is recurrent at a 25% probability (25-year) whereas the same value is recurrent at a 99% probability (100-year) in SC DOT 24-hour design IDF curves. In both cases, the intensity of storm events shows large differences because the 100-year storm event occurred at a 25% probability (25-year) while the SC DOT design IDF curves underestimated those storm events. This may increase the risk of infrastructure failure particularly in urban drainage systems.

Summary and Conclusions

Nonstationary analysis revealed extreme events show stronger correlation with ENSO than PDO. Modeling results support existing trends in all parameters of extreme distribution. Location parameter trends are explained by sudden multi-year changes in catchment behavior often as a result of anthropogenic activities (e.g. dam construction). Trends in scale and shape parameters indicate increases in the intensity, magnitudes, and spatial patterns of extremes as a result of climate change.

The extent to which changes in watershed response to flooding are caused by hydro-climatic variables, anthropogenic changes, or a combination of the two is difficult to assess and remains a challenging question in hydrology. The data and the algorithms are freely available upon a request to the first author.

Floodplain Geomorphology and Circulation

Raymond Torres and Brandon Cook, Department of Earth and Ocean Science

Introduction

South Carolina floodplains persist along river corridors, and they contain vibrant ecosystems that extend tens of kilometers away from the active channel. Floodplain ecosystems provide substantial benefits to society in that they are considered kidneys of the landscape because they filter water, sequester carbon, attenuate flood waves and support a vibrant recreational industry. Hence, floodplain processes such as frequency of inundation and complex flow dynamics help sustain rich habitats that depend on abiotic processes. The purpose of this study is to observe inundation flow complexity as flood stage varies.

Methodology

The study site is the Santee River floodplain near Jamestown, South Carolina. We installed three tide gauges in an quasi-equilateral triangle configuration that were used to measure water surface elevation every five minutes, and we installed one current meter near the center of the triangle. The regional water flow direction was determined from the tide gauges and that was compared to the instantaneous measurements of current speed and direction from the current meter. We also measured ground surface elevation in and around the triangle. Ground surface elevation and water surface elevation were all referenced to a common vertical datum.

Results

The high rainfall conditions of winter 2015-2016 produced flooded conditions at the study site a total of six times during the two-month deployment. The largest flood produced a floodplain inundation that lasted for eight days, with a maximum water depth of 0.94 m. The observed free surface shows highly complex flow direction and magnitude, including complete flow reversals. These observations were also detected in the instantaneous measurements. The complex flow structure varies with the submergence and emergence of the floodplain landscape. The initial inundation occurs primarily from the main channel to the west but the subsequent emergence occurs due to flows to the east and north. Hence, the submergent and emergent flow paths do not necessarily follow the same pathways. Typically water parcels enter the triangle from one side and leave by a different side. Between the submergent and emergent conditions both the regional and local flow directions were essentially parallel to the main channel and in the downstream direction.

The instantaneous readings revealed flow speeds of 0.04 to 0.44 m/s although 85% of the values were less than 0.16 m/s. The peak values were associated with the emergence of the floodplain surface, as water left the area in a general direction toward two small creeks, one to the northwest and one to the southwest. In comparing the regional flow direction to the instantaneous directions we found that the two observations were not in complete agreement most of the observation interval. In particular the regional values were typically more southerly, by about 8-22 degrees. Also, the regional readings had a lag time of about 0.6 to 1.4 hours. Finally during peak water levels the free surface had nominal slope and corresponding velocity but water continued flowing in the downstream direction at < 0.05 m/s.

Summary and Conclusions

There exists a paucity of data on the fine details of floodplain inundation and water circulation and yet these processes are typically assumed to control many of the attributes of floodplain material cycling, transport and accretion. We used regional and local water flow direction readings and a high precision topographic map to investigate the flow complexity over an inundated floodplain. There are three stages of flow conditions. During floodplain inundation flows are initially from the north and later predominantly from the east. Higher stage flows become more uniform and predominately from west to east. When the floodplain is fully inundated flows are slow and to the southeast. As the system becomes emergent flows are generally to southwest but short-lived flow reversals can occur causing water to flow to the north.

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