



Water AND Heat: Intervening in Adaptation Hazard Bias

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After centuries of adapting to coastal living, increases in stormwater and tidal flooding events, along with projected sea level rise, led Charleston, South Carolina, USA to define flooding as an existential threat to the city. With billions of planned flood management projects underway, and additional billions of federal disaster flood recovery funds allocated to the State of South Carolina, the Governor's office established a South Carolina Office of Resilience in September 2020, with a focus on water management. The City of Charleston developed its own Flooding and Sea Level Rise Strategy. Simultaneously, the fourth National Climate Assessment pointed to heat health risks and projected costs of lost labor productivity concentrated in the Southeast, yet local recognition of heat as an equivalent threat to flooding was not apparent. Although Charleston's All Hazards Vulnerability Assessment included extreme heat as a significant hazard, without a group focused on heat, ongoing work in the city continued to prioritize water management as annual flood events rapidly escalated. This narrow adaptation framing was further solidified as funding focused on flood recovery and adaptation and technical experts worked within water-related boundaries. These interacting forces led to Hazard Bias, an inherent organizational process of reinforcing focus on a single hazard in the context of compound, complex hazard risks. To adapt to increasing heat, Charleston will need to raise compound risk awareness and adjust its capital investments in resilience to be inclusive of heat mitigation and adaptation as well as water. Yet in 2020 Charleston lacked basic urban heat data, technical expertise, and a strong source of motivation to develop a prioritization approach for recognizing multiple risks and complementary adaptation opportunities in those investments. Recognizing the inherent bias, a new coalition of heat researchers, practitioners, and health experts launched a tripartite heat-health research program and spurred the development of a new heat network in Charleston. The network reduced hazard bias by raising heat-health risk awareness and by intervening in adaptation planning to broaden water-only considerations to be inclusive of water AND heat. This paper provides a detailed case study how the intersections of multiple networks, messengers, and messages contributed to broadening the local resilience agenda from a "hazard bias" and how the lessons learned during this transformative process further reveal health inequities.

Keywords: hazard bias, climate adaptation, extreme heat, health inequities, flood management

INTRODUCTION

Charleston, South Carolina, centered on a peninsula at the confluence where the Ashley and Cooper Rivers join the Atlantic Ocean, is one of the oldest cities in the USA. For its 300 plus years, the rivers and ocean have been obvious dominant physical influences in where and how the city developed. The battery walls were constructed to protect the lower part of the peninsula from the ocean waves; low-lying areas were filled to create more space to build, and a major port connected Charleston to global trade. The climate, with the exception of hurricanes, was a lesser factor. Years of drainage, pumping and piping enabled former swampland to become habitable while the wealthiest Charlestonians escaped summer heat by traveling inland to the cooler Blue Ridge mountains.

Fast forward to 2010 (or so) and after centuries of adapting to the coast, awareness of Charleston's relation to the sea was shifting to a focus on the threats posed by rising relative sea levels and the increasing frequency of tidal flooding. Tidal flooding events that had occurred an average of <1 time/year in 1920s were occurring an average of 42 times per year [National Weather Service (NWS), 2022b]. Globally, temperatures were also rising, but local temperature change did not elicit dramatic concerns. The sultry summer weather was normal. Rather, the increase in sunny day flooding and the prediction of further sea level rise motivated Mayor John Tecklenburg to consider flooding as an "existential threat to the city" and prompted the US Army Corps of Engineers to propose an estimated \$1.4 billion sea wall to provide additional protection to Charleston's peninsula, the heart of its economy. Paired with nearly \$2 billion of Federal Disaster Recovery funds allocated to the State of South Carolina from 2015 to 2021, much of which was directed to coastal counties, and nearly all of which focused on flood recovery, funding was clearly not the primary problem, but instead, it was recognition of heat as an significant threat.

Still, in other cities and many research fields, heat was receiving more attention with findings relevant to Charleston. The fourth National Climate Assessment [US Global Change Research Program (USGCRP), 2018] pointed to heat health risks and projected costs of lost labor productivity concentrated in the Southeast. Research in North Carolina highlighted the increased odds of pregestational births associated with days of high temperatures but less than heatwave conditions (Ward et al., 2019). Moreover, concern over energy insecurity as a dimension of poverty was rising in association with heating and with cooling (Hernández, 2016). The Union of Concerned Scientists (2019) projected that Charleston-North Charleston would go from a historical average (1971–2000) of 74 days above 90°F/year to 123 such days/year by midcentury (2016–2065) under current emissions trends. The COVID 19 pandemic was making the depth of racial health disparities associated with these hazards and exposures more visible (Phillips et al., 2021).

Situated in this context, this paper reflects our shared experiences in how the intersections of multiple networks, messengers, and messages contributed to broadening the local resilience agenda from a "hazard bias" toward flooding to be inclusive of heat and how the lessons learned during

this transformative, focus widening process further reveal health inequities. Hazard bias is the inherent organizational problem of single hazard focus in the context of compound and connected hazard risks (Barnes and Temko, 2022). For Charleston, compound and connected hazard risks include the coincidence of hurricane/storm and heat seasons (Zscheischler et al., 2018; Raymond et al., 2020). Hazard bias appears to stem from the combination of (1) disparate lived experiences and their histories reinforced by (2) the focus of disaster declaration typologies and associated funding, and (3) the siloing and reinforcement of depth over breadth of technical expertise (Barnes and Temko, 2022). This paper offers an application of this new concept as a way of identifying an inherent challenge in climate adaptation planning.

While each of these factors has been identified individually as a barrier to adaptation, the reinforcing feedbacks among them have received less attention. A narrowly focused adaptation process has the potential to result in investments that neglect opportunities to address the risks to the historically underserved and socially vulnerable communities and miss chances to take advantage of complementarity and reduce competition among adaptation strategies.

In the Charleston context, being from an underserved and socially vulnerable community almost serves as a proxy to heat-health risks as census tracts with low canopy cover map closely to those with high values on the Center for Disease Control Social Vulnerability Index (City of Charleston, 2021a). Such environmental injustice amplifies inequities, including inequitable exposure to extreme heat and limited resources to deal with such exposures (Hoffman's, 2017; Hoffman et al., 2020; Hsu et al., 2021). While the body of literature on extreme heat and health continues to grow alongside global temperatures, there's more to do to raise awareness and to substantively adjust public investments to be more inclusive of heat mitigation and adaptation strategies (Keith et al., 2019).

Herein, we describe the intertwined efforts required to overcome hazard bias in Charleston, recognizing the escalating risks of heat alongside flooding, and the pathways taken to date. This case study offers concrete examples and lessons learned, including ways of seeing risks more fully, of understanding inequities as risk magnifiers, and the types of collaborations necessary to do so. While progress was made in increasing the awareness of heat threats and patterns of vulnerability, it is not yet clear if the actions taken to address the threats will focus on the needs of socially vulnerable and historically marginalized communities. Future efforts to design and implement adaptation strategies will still require distributive and procedural justice and equity as central guiding concepts.

CHARLESTON'S CLIMATE CONCERNS

Charleston's first major climate change planning effort was the "2015 Sea Level Rise Plan", followed by a second edition, titled "Flooding and Sea Level Rise" in 2019 with mentions of trees for flood and heat mitigation (City of Charleston, 2015, 2019b). In 2020, the City of Charleston completed its first City Vulnerability

Assessment (City of Charleston/Fernleaf Interactive, 2020) which identified extreme heat as a significant current and growing future climate risk consistent with the highest confidence level in IPCC Sixth Assessment Report [Intergovernmental Panel on Climate Change (IPCC), 2021]. According to the US Climate Resilience Toolkit (USCRT), the City expects to have triple its current number of extreme heat days by the end of the century [US Climate Resilience Toolkit (USCRT), 2022], but has no designated financial resources for heat adaptation as compared to its flooding and sea level rise projects [City of Charleston, 2022a,b; US Army Corps of Engineers (USACE), 2022]. While the 2022 approved General Operations Budget acknowledges the need for warming shelters, specifies funding, and identifies non-profit collaborations to provide such shelters during winter months, there are no reciprocal budget items for cooling shelters in summer months (City of Charleston, 2022a, p. 215). In fact, there are no mentions of extreme heat management in the 2022 budget.

Compounding this financial challenge, many in the South assume heat is manageable as the presumption of “it’s always been hot here” may undermine the ability to meaningfully address heat. Howe et al. (2019) found that on a scale of 0–100 (low to high), residents of Charleston County, on average, reported ranking extreme heat event risks at 41, one point above the national average. At the national level, this research also reported that, consistent with differences in the vulnerability of residents, responses from poorer neighborhoods and those with larger minority populations generally have higher perception of extreme heat risks than wealthier neighborhoods with more white residents (Howe et al., 2019).

While daily heat exposures are distinct from heat waves, heat is the nation’s deadliest weather-related risk (**Figure 1**). The NWS [National Centers for Environmental Information (NCEI), 2022] identified nine days with “excessive heat” events in Charleston between 1996 and 2020, defining excessive heat as a combination of high temperatures and high humidity (which together form a heat index) that can impact human health [National Weather Service (NWS), 2020]. An excessive heat event is recorded/reported when heat indices “meet or exceed locally/regionally established excessive heat warning thresholds” (Strassberg and Sowko, 2021). The recent and less publicized wet bulb globe temperature climatology for the Southeast indicates that Charleston averages between 10 and 15 days a year with at least 1 h of temperatures above the black flag level at which point, the US Army guidance indicates that heavy work be reduced to 15 min accompanied by 45 min rest.

Community members rely on air conditioning, the ability to afford it, and a stable power grid to cope. Unfortunately, those with less means struggle with energy security, including access to air conditioning or affordability of energy, increasing health disparities, and impacting heat-related co-morbidities among more vulnerable populations (Hernández, 2016; Jessel et al., 2019). Moreover, those who suffer most have the least visibility as evidenced in the documentation of energy poverty in Charleston County [CISA, Carolinas Integrated Sciences and Assessments, 2019b; Texas Energy Poverty Research Institute (TEPRI) and Southeast Energy Efficiency Alliance (SEEA), 2021].

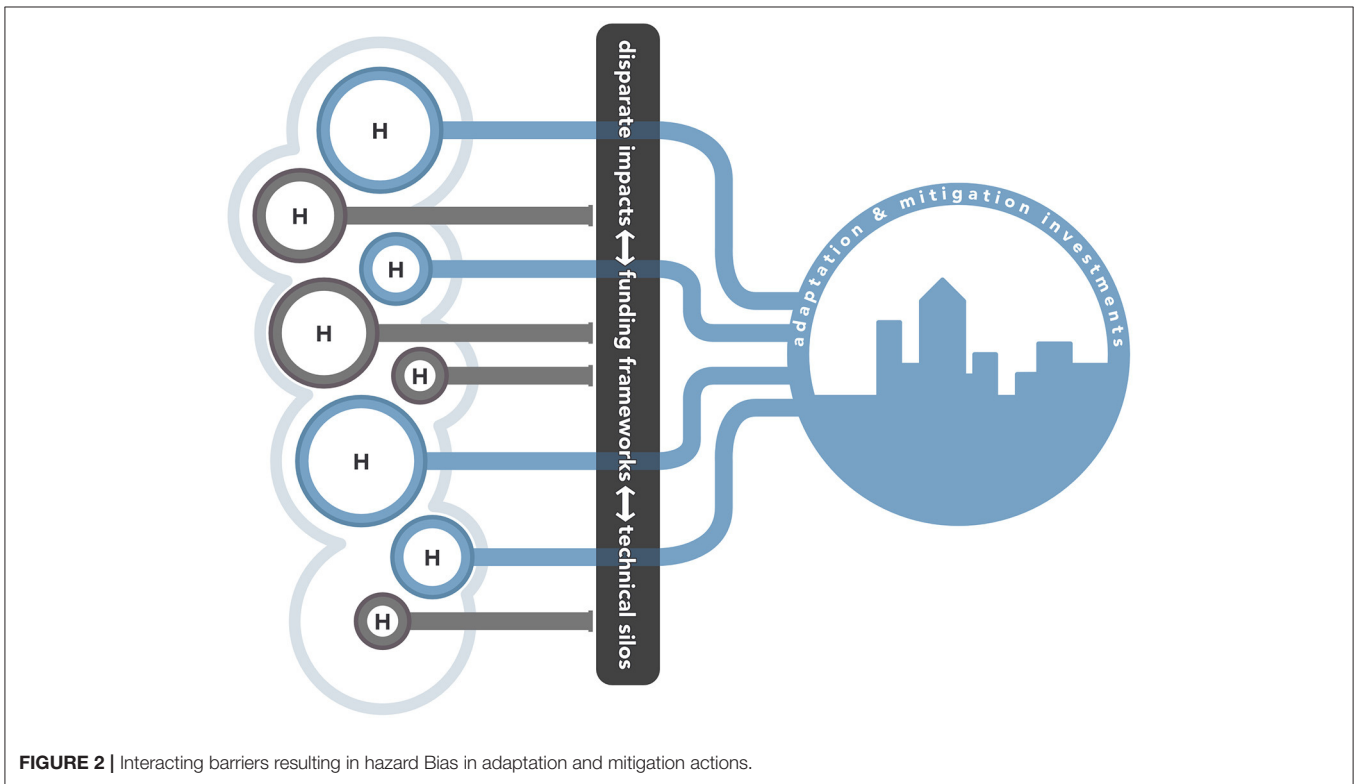
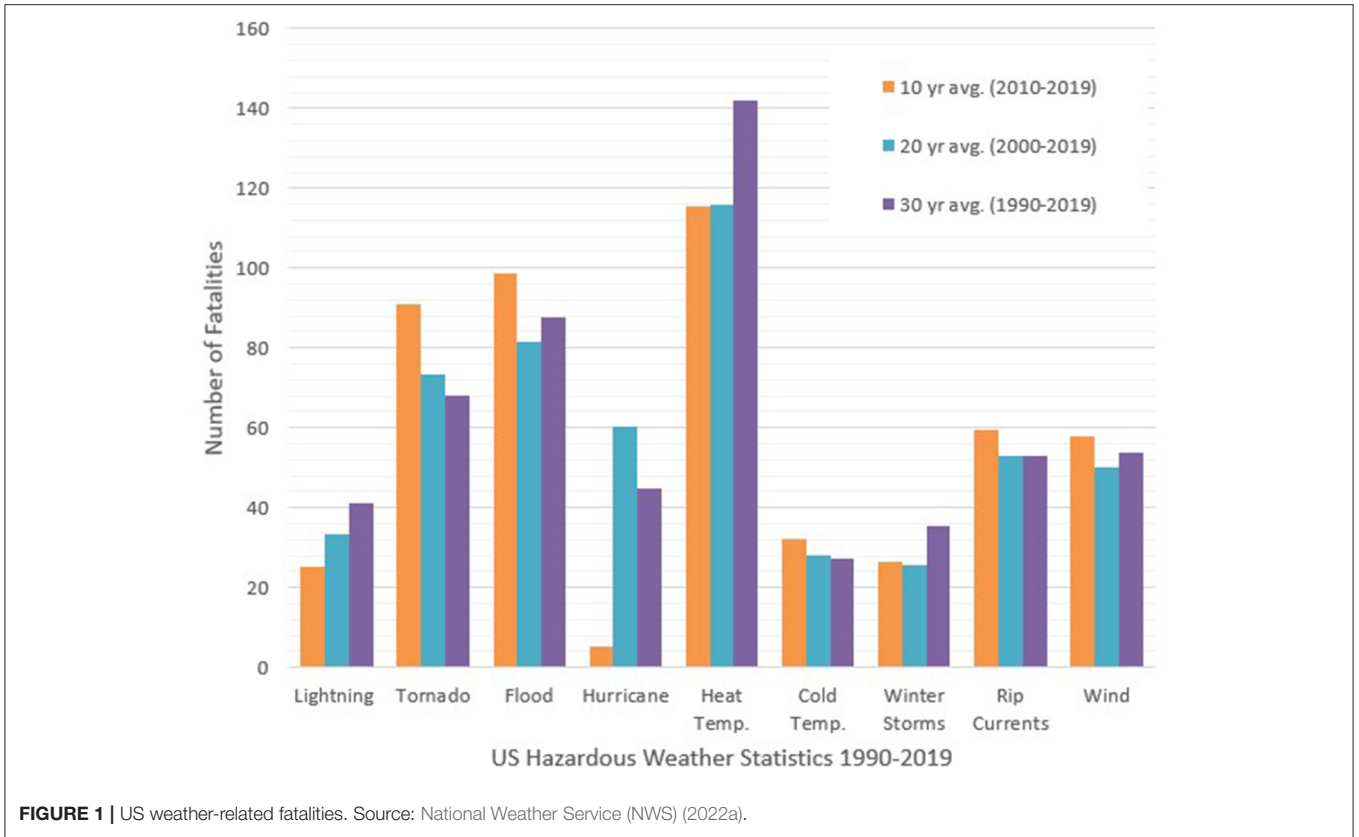
While in recent years there have been efforts to provide some senior citizens with air conditioners, to better weatherize homes, and to help with energy bills, these short-term solutions lack comprehensiveness and do not solve Charleston’s growing heat problems (City of Charleston/Fernleaf Interactive, 2020).

To stave off worsening conditions for those most vulnerable, Charleston should raise compound risk awareness and adjust its capital investments to be inclusive of heat mitigation and adaptation. Yet in 2020, Charleston lacked basic urban heat data, technical expertise, and a strong source of motivation to develop a prioritization approach recognizing multiple risks, differential susceptibility, and complementary adaptation opportunities in for those investments to serve those most vulnerable to extreme heat. Although Charleston’s Vulnerability Assessment identified extreme heat as a hazard, including much of the city as medium to high impact areas, extreme heat was not the focal point of the assessment and deeper technical analyses were not included (City of Charleston/Fernleaf Interactive, 2020). The screening level GIS analysis overlaid the number of households with members over 65 and number of households living below the poverty line with percentage canopy cover at the census tract level (City of Charleston/Fernleaf Interactive, 2020). Charleston’s flood-related issues were, and remain, priorities, given their growing incidences and the capital and operational costs associated with those incidences. In turn, there were no motivating programs, project proposals, or other incentives geared toward recognizing the parallel growing threat of extreme heat and the potential for co-beneficial solutions alongside water management. Without such support and incentives, there were no technical experts retained to address heat alongside flooding concerns nor inclusion of heat mitigation in proposals for water management. Instead of including heat risk considerations in ongoing discussions about water management, particularly where green infrastructure solutions might offer multi-benefit strategies and where consideration of heat vulnerability might include more socially vulnerable areas, water management was the hazard focus. Exploring the cultural, economic, and technical constructs that lead to Hazard Bias provides insights to the changes required for such prioritization to occur. Framing this exploration, **Figure 2** illustrates how the interactions among Disparate Impacts, Funding Availability, and Technical Expertise, become filters that restrict which hazards become the resultant investment priorities in cities.

Disparate Impacts

The impacts of heat and flooding are distributed differently among entities in the Charleston area. While there is little specific documentation about heat impacts in Charleston, there is considerable relevant research documenting differences in vulnerability for individuals based on health and exposure. The impacts of recurrent flooding on individuals and the City itself are much better documented locally and nationally.

For those with the means to cool their homes and businesses through air conditioning and weatherization, for whom the cost of energy is not a burden, and for those with the choice and means to relocate away from risky areas should the need arise, heat risks are less apparent. In the city’s 350+ year



history, that has always been the case. However, for those whose daily work exposes them to extreme heat (outdoor workers, un-air-conditioned warehouse workers), whose co-morbidities exacerbate their reactions to extreme heat exposure [Global Heat Health Information Network (GHHIN), 2022], whose personal decision-making lacks informed awareness of, or choice to avoid, heat risks, extreme heat represents material risks to life and livelihood.

Exposure to extreme heat impacts people in Charleston in differing ways. For example, prior to the COVID-19 pandemic, Charleston welcomed over 7 million tourists annually (College of Charleston, 2019a). Tourists represent a vulnerable group as many are unacclimated to Charleston's warmer weather. Comparatively public transit riders are better acclimated as they are primarily local residents who rely on public transit due to limited access to personal vehicles or due to incentive programs by employers, such as the Medical University of South Carolina (MUSC), or the College of Charleston which encourage public transit ridership given their focus on emissions reductions and due to parking constraints on Charleston's peninsula (College of Charleston, 2019b; Medical University of South Carolina, n.d.). While these local groups are relatively better off than tourists, waiting at transit stops still results in additional heat exposures.

Heat health impacts, such as those captured by emergency responder data or heat-related mortality, are not yet well tracked or discussed regionally although more recent research on the public health burden of extreme heat, and on energy insecurity as a proxy for heat-health risk, continues to improve shared understanding (Burkart et al., 2021). While some local groups help senior citizens to weatherize homes and obtain air conditioners (Sustainability Institute, 2022; Project Cool Breeze, n.d.) these efforts are relatively small compared to the scale of Charleston's need and receive scant attention compared to its risks. For example, in 2016, the Post and Courier, Charleston's local newspaper, interviewed an emergency medicine physician who described child athletes dying every year from exposure to extreme heat, arguably the most understandable heat-health risk in regional discussions Johnson (2016). Yet this same article referenced research from Fisher, Sheehan, and Colton (2017) noting South Carolina's low-income families spend up to ¼ of their household income on energy. However, to date, there has been no other structured research to reveal these challenges, such as the comparison of LIHEAP (Low-Income Home Energy Assistance) recipient locations, flood-prone areas, and public transit ridership, a key set of interrelated indicators and proxies that could shed light on the compound risk areas and the opportunities for greater integration of heat into water management planning. Thus far, the research team has relied on these reports alongside the described data collection, recognizing that to truly understand the impacts of living with extreme heat, the next phases of research must delve into communities directly and learn more through their stories.

Comparatively, with chronic flooding from cloudburst events that lead to flooding of inland streets, high tides, and King Tides, storm surge flooding at the coast, and increasing sea levels and groundwater, Charlestonians' experience several types of water hazards is well documented. The City's 2015 Sea Level

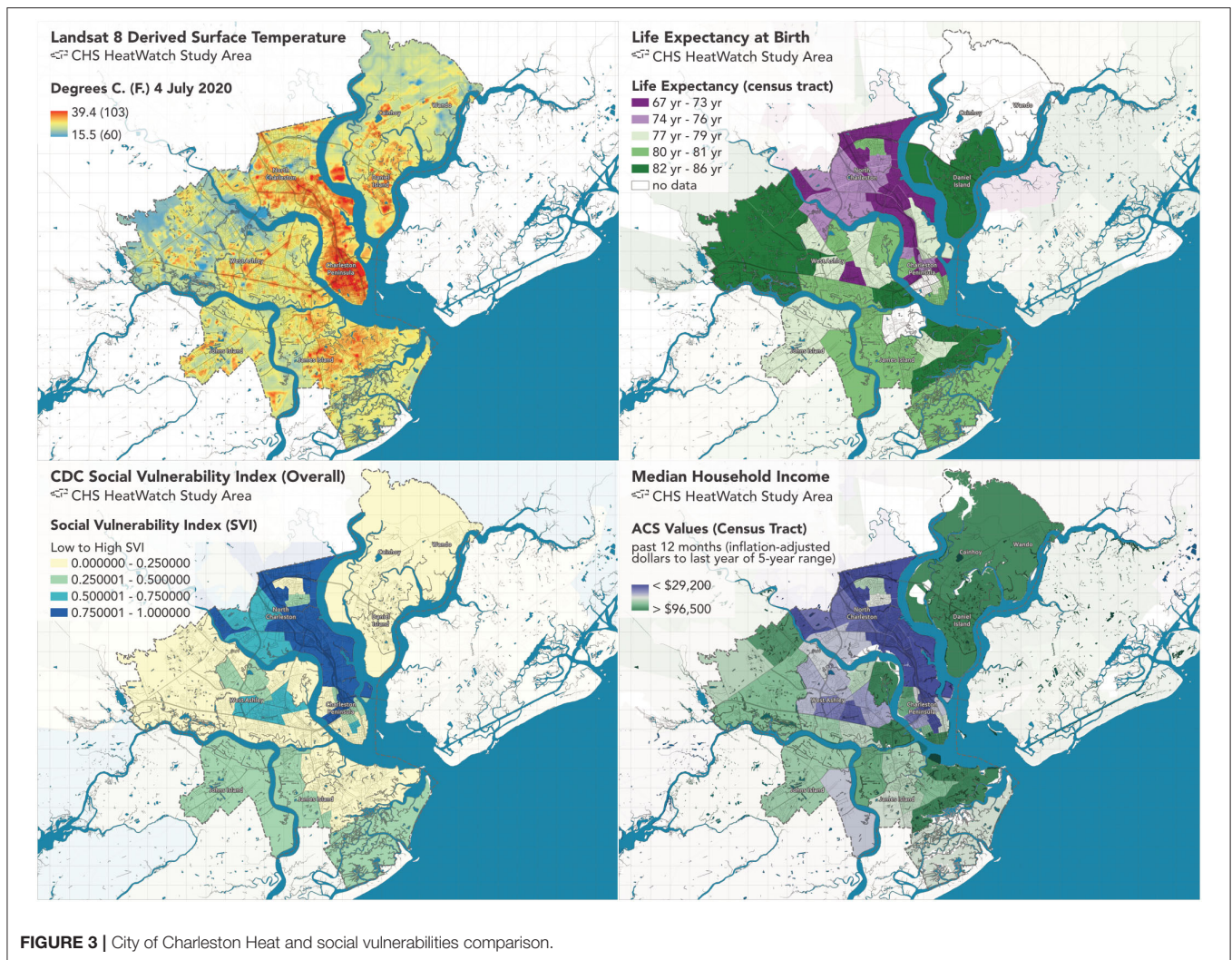
Strategy emphasized that "by 2045, the City is projected to face nearly 180 tidal floods a year" (City of Charleston, 2015, p. 1). The City of Charleston estimates that each flood event that affects the Hwy.17 Septima Clark Parkway—cross town highway costs \$12.4 million (in 2009 dollars). The City further projects \$1.53 billion in gross damages and lost wages taking into account impacts on long-term job creation; restricted access to commercial properties and medical centers; impacted tourism and business activity, lost productivity spent navigating flooded areas; and extensive police resources focused on damaged and "rescued" vehicles (City of Charleston, 2015). The report of the City of Charleston's Special Commission on Equity, Inclusion, and Racial Conciliation (2021:23b) includes a section on Health Disparities and Environmental Justice which includes multiple long-term goals to improve health and specifies, "Prioritize flood mitigation strategies that address racial equity and environmental justice" as a long-term goal but does not mention heat. These futures emphasize water priorities for the majority and the historically underserved even as a minority cannot afford to cool their homes and lack alternatives, such as cooling centers, for respite.

Unsurprisingly, as illustrated in the map comparison of Charleston's surface temperatures with life expectancy, social vulnerability, and income, Charlestonian's engrained inequities represent a chronic backdrop to the experience of extreme heat (Figure 3). Understanding the linkages between vulnerability and poverty, as well as individual and community capacities to cope, requires a deeper understanding of inherent societal inequities and their interrelatedness to disaster risk responses and to governance approaches lacking contextual, procedural, and distributional equity (Eriksen et al., 2007; Lavell et al., 2012; Marino and Ribot, 2012).

Disaster Declarations

As of January 2022, there have been no federally declared heat disasters anywhere in the United States or its territories even though, since 1991, heat-related fatalities far outpace those by any other disaster, sans COVID-19, in the United States [Figure 1; Federal Emergency Management Administration (FEMA), 2022]. Instead, drought is commonly designated, reinforcing the focus on capital loss [NOAA National Centers for Environmental Information (NCEI), 2022].

While the majority of recovery funding in the United States is federally appropriated, following the 1948 Midwest flood and the subsequent development of the Disaster Relief Fund, this is not the only source of disaster funding. States and Local governments also fund recovery. However, the Federal Disaster Declaration and associated appropriation is the modern funding mechanism for the Robert T. Stafford Disaster Relief and Emergency Assistance Act, passed in 1988, that, today, structures much of the Nation's disaster recovery and mitigation efforts (Painter, 2022). These emergency or disaster declarations, form the foundation of FEMA's disaster response programs and, as well, responses managed by the Department of Housing and Urban Development (HUD) (Robert T. Stafford Disaster Relief and Emergency Assistance Act, 1988).



Since 1953, there have been 4,632 discrete emergency or major disaster declarations in the United States or its territories [Federal Emergency Management Administration (FEMA), 2022] and each is classified by the perceived threat causing an economic loss. Recovery and/or mitigation funds are then earmarked to address specific economic losses, typically biased toward capital asset losses, specific to the designated event. While this process makes sense in the context of Congress' role in managing the appropriation of public funds, the bias of disaster declarations toward capital loss associated with a discrete event does little to address other compounding, complex risks and their associated (not necessarily economic) costs. In the case of heat, the systemic issues here are substantive. As (Keith et al., 2019, p. 2) note, heat risks are “distinct than [sic] other climate risks for multiple reasons, including the historic lack of governance and legal regulatory structures.”

In the state of South Carolina, storms, wildfires, and COVID-19 comprise all declarations in the last decade. Without a disaster declaration, there are no federal recovery funds [Federal Emergency Management Administration (FEMA),

2022]. Without recovery funds, the choice for capital project improvements relies on state and local government interests, and to date, those have not focused on heat.

The reason for alternative foci is clear as since 2015, \$1.8 billion in recovery funds followed the multiple disaster declarations for storm recovery alone in South Carolina (The Nature Conservancy Southern Environmental Law Center, 2022). In parallel, the Governor of South Carolina appointed a statewide Floodwater Commission to focus on storm-related flooding (State of South Carolina, 2021). The State of South Carolina Office of Resilience (SCOR) intends to emphasize flooding in its first statewide resilience plan as was specified in the authorizing legislation and South Carolina remains in recovery mode from 2015 storms as of January 2022 (Disaster Relief and Resilience Act, Title 48, Chapter 62, 2020, State of South Carolina, 2022). All subsequent disaster-declaration recovery works are also in process including those related to COVID-19 recovery. At this same time, the US Army Corps of Engineers is in the midst of a 3×3 (3 years and under \$3 million) study for a Storm Surge Barrier

for Charleston [US Army Corps of Engineers (USACE), 2022]. In parallel, numerous ongoing county and city capital projects address chronic flooding. Still others are seeking grants or innovative financing to address flooding (City of Charleston, 2020b, 2022b). While these efforts are individually and collectively important for the State of South Carolina and for Charleston to manage growing flood risks, none of these efforts includes requirements to consider heat mitigation as a co-benefit, even as several encourage the use of nature-based solutions, which in turn serves to further deepen technical expertise on, and awareness of, flood management.

Technical Expertise Silos

Given these planned investments technical experts flock to flood-prone areas offering helpful contributions toward flood reduction and toward living more resiliently with water. These water experts focus on how to address inland and coastal flooding, bringing tools and frameworks to bear on the increasing problem of urban water management. The tools and trainings are frequently discipline-specific (floodplain managers, civil engineers, hydrologists, landscape architects, etc.). The deepening of such technical expertise in water management further isolates practitioners from more holistic thinking about climate change, as evidenced by the Dutch governmental priorities on flooding and their own challenges in developing a country-wide approach to extreme heat [Klok and Kluck, 2018; Amsterdam Institute of Advanced Metropolitan Solutions (AIAMS), 2020]. In Charleston this same framing reinforces a hazard bias toward water. For example, the 252-page Dutch Dialogues Charleston report (City of Charleston, 2019a) demonstrates the lesser interest in intersections between flooding and heat with only nine general mentions. Those instances are typically focused on co-benefits of water strategies, such as, “In addition to the work on slowing, storing, redirecting, and adapting to water, complementary solutions would help. Many solutions for water also help to reduce urban heat.” (City of Charleston, 2019a, p. 234). Similarly, the USACE 3 × 3 focuses solely on the storm surge barrier, and even as its critics offer more inclusive nature-based solutions, those proposals lack significant emphasis on heat mitigation or adaptation (Imagine the Wall, 2020). These solutions focus on water ONLY, creating the impression there is a necessary choice between addressing flooding OR other hazards. The hazard bias and associated siloing of expertise increase the propensity to focus on technical solutions over actions that are more intertwined with societal concerns and strategies to reduce vulnerability through socio-political interventions (Kehler et al., 2021).

The one spot where *AND* holds more power than *OR* is in the South Carolina 2020 State Act 163, which requires all municipalities to address water *AND* other hazards in each municipal comprehensive plan update (State of South Carolina, 2020). The Act intends to motivate a more complete understanding of risks, but it faces an uphill push given the lived experience in Charleston. However, its language, while more inclusive of other hazards, also prioritizes water.

Despite the implicit hazard bias toward flooding, fortunately, there is growing concern about heat warnings in general.

Under the Biden Administration, in 2021, OSHA implemented guidance for worker health as related to extreme heat (OSHA, 2021). The National Integrated Heat Health Information System (NIHHIS) team at NOAA ran its third HeatWatch campaign and hosted numerous events to generate a culture of heat research and awareness building (National Integrated Heat Health Information System (NIHHIS), 2022). The Lancet, a leading international medical journal, emphasized the importance of better heat-health risk awareness (The Lancet, 2021). Yet in Charleston, ahead of this research program, there were two public resources for heat warnings. One was the Charleston NWS Forecast Office (National Centers for Environmental Information (NCEI), 2022), which uses a heat index of 105 (well above the black flag of 92 Wet-bulb globe temperature (WBGT) (US Department of Commerce, NOAA, 2022). The second appears in Charleston’s municipal code and focuses on heat risks to carriage horses used in tourism. It provides detailed practices for monitoring the heat exposure, stress, period of water availability between tours, and other working conditions (City of Charleston, 2020c, 2022b). It was within this context that our team began building its research and engagement program.

The effort to reach diverse audiences and engage the community at many levels relied on the efforts of many individual researchers, consultants, MUSC, the Charleston Medical District Advisory Group (CMDAG), Citadel, and city leadership and staff who participated in the research and promoted the importance of the research through their networks. These boundary spanners (Goodrich et al., 2020) collectively tackled, and continue to address, ways to raise heat-health awareness in Charleston. The authors, Barnes and Dow, facilitated this broad collaboration, but the emerging outcomes are a collective accomplishment. The core research team is recognized in the acknowledgments.

DETAIL TO UNDERSTAND THE KEY PROGRAMMATIC ELEMENTS

Coming to a deeper understanding of heat-health threats highlighted the significance of two processes. An established network of trusted relationships formed the core of an expanded research agenda and partnerships between the CMDAG, CISA, and the City of Charleston. At the same time, members of those networks leveraged other connections and interests, self-organizing to broaden dialogues, participants, and outreach communications. These processes drew on distinct information sources and operated at different spatial and temporal scales, with residents making daily decisions about personal exposures and the City and the CMDAG developing long-term capital investment plans intended to integrate resilience into the built environment. **Figure 4** provides a timeline of events discussed in this section as they relate to the growth of Charleston’s focus on water management since 2014 as compared to the 2021 introduction of an All Hazards approach, inclusive of extreme heat. Since 2021, the network has focused on developing a shared understanding of extreme heat risks and conducting further research heat-health impacts. Next steps include the development of practical

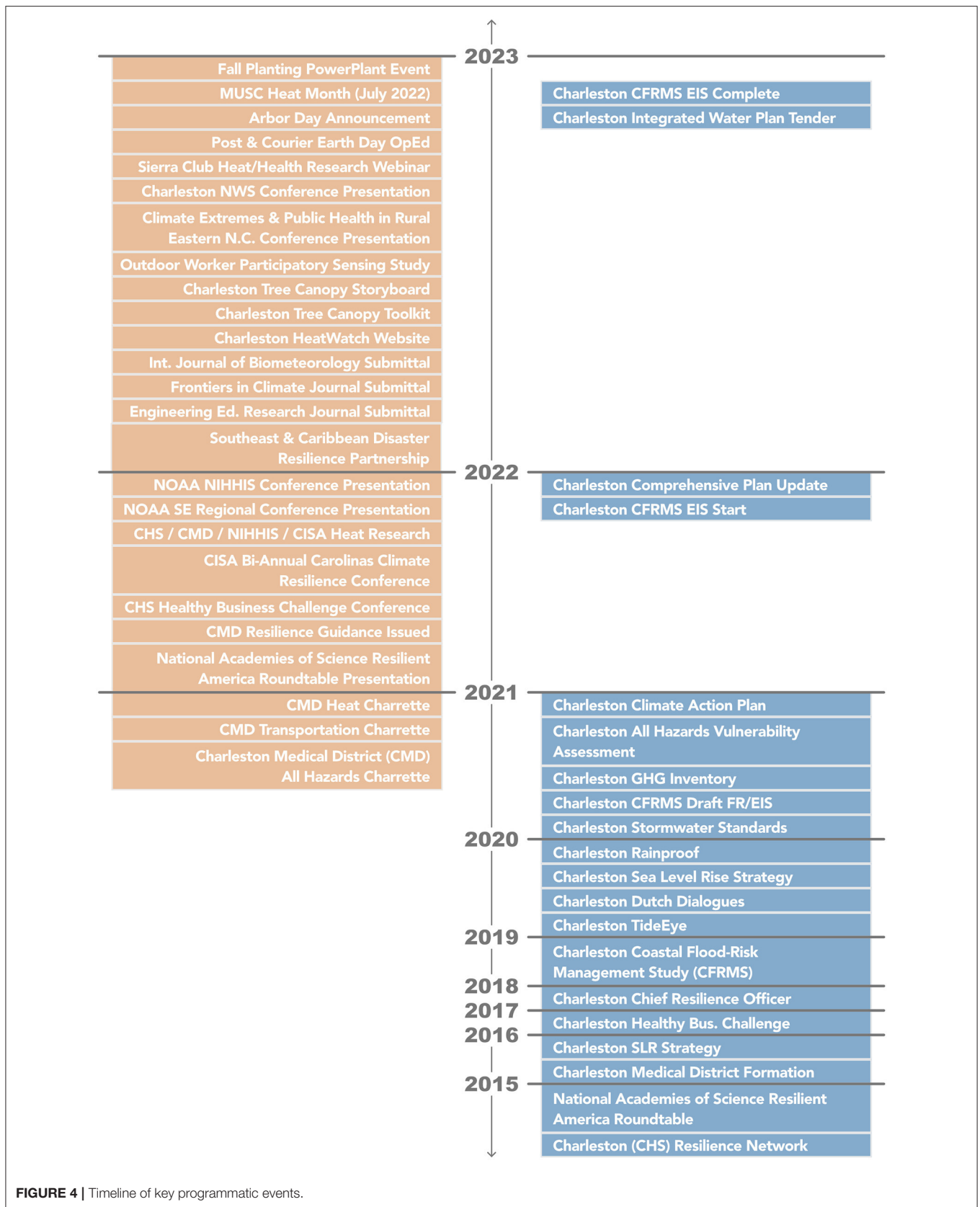


FIGURE 4 | Timeline of key programmatic events.

solutions, in concert with water management, to reduce extreme heat.

The process began from a small but significant core effort to develop an adaptation roadmap for the Charleston Medical District (CMD), a critical regional medical resource and the largest employment center in the region. Access to the CMD is frequently disrupted by flooding and given its role as a critical medical facility, securing the CMD is a priority in Charleston. With years of effort to develop near-term coping strategies, such as buying a boat to ferry patients on high tide days, and advocacy for mid-term and longer-term flood-related capital projects, extreme heat was not a priority.

Following the Charleston Dutch Dialogues in 2019, the CMDAG and Climate Adaptation Partners (CAP) began working on a district-specific resilience strategy, hosting charrettes on flooding, transportation, and funding for resilience. During early strategy meetings, initial heat risk conversations found little resonance even as the City of Charleston published its first Vulnerability Assessment, which emphasized the need for an all-hazards approach to resilience inclusive of heat, albeit not its priority (City of Charleston/Fernleaf Interactive, 2020). The everyday hazard of heat, situated across 350 years of warm, humid days, and limited heat warning systems, struggled to get attention when the direct experience of the threat was less impactful to decision-makers who lacked awareness of the relationships between heat, health, housing, and energy security, and whose daily work required immediate responses to flooding.

In the spring of 2020, one conversation became the transformative moment in heat risk perception. As part of a grant proposal development, the CAP/CMDAG team reached out to physicians who might partner on climate-related health research. During such a meeting a well-respected senior physician mentioned almost casually that several patients had passed out from heat while walking from their cars to their appointments. For those physicians in the meeting, heat-health was a known issue, but rarely were these same physicians in planning meetings for the campus. This realization of patient risk on hospital grounds moved heat from the background to become relevant to the CMD's healthcare mission. The CMDAG became more supportive of exploring heat health risks and implications for planned investments.

Next CAP prepared LandSat images of surface heat in the CMD to help illustrate the extent of the issues. The CMDAG then agreed to the conduct of a surface heat sampling pilot. Drawing from Hoffman's (2017) protocols, CAP used a FLIR ONE thermal imaging camera to capture skin surface temperatures on a typical summer day in Charleston (Figure 5). This sampling approach, relatively new with affordable access to thermal imaging cameras, generates useful visual representation of heat which enables community scientists and members to better understand heat in relation to various surfaces. The results showed multiple hot surfaces, including unexpected surface temperatures in areas intended for respite and in areas recently renovated to encourage greater public use. Many of these were areas where patients, faculty, staff, and visitors gather. After presenting these data to the CMDAG, the network connected CISA and CAP,

launching the collaboration (the team) for Charleston's larger heat research program.

The team shared the initial skin surface heat observations in meetings with CMD master planning and operations teams to build further interest in better characterizing heat risk as related to planned capital investments, or readiness of energy resources for greater heat exposures. In parallel, as part of a heat charrette, CISA team presentations highlighted the importance of advancing the understanding of initial surface heat images by investigating highly localized WBGT to better characterize human heat stress by considering temperature, humidity, and the impact of solar radiation and winds. The team also emphasized the need to better characterize the personal exposure and stress of outdoor workers through using wearable heat and humidity sensors together with GPS-enabled heart rate trackers as they moved around the campus during the day. With this growing collaboration, the CMDAG recognized the importance—the health emphasis—of better understanding CMD exposures to extreme heat and agreed to collaborate with CAP and CISA on a more fully developed heat research program for the summer of 2021. CISA funded the research for personal monitoring and for WBGT sampling while CAP volunteered time for the coming year. With these pieces in place, in December 2021 the team then secured a NIHSS HeatWatch grant to map the urban heat island of the greater Charleston area. Building on the growing concern and commitment of the CMD to addressing heat, as part of the application, the City of Charleston committed to use the heat maps and data to inform their future actions.

In this context, the Charleston Heat Research team effort was launched, a tripartite effort to capture outdoor worker exposure at the CMD and nearby Citadel Campus, WBGT sampling in the same areas, and a city-wide HeatWatch sampling that included these same areas. This effort garnered further support and broadened a coalition of collaborators. This led to heat health risks finding an institutional home in MUSC's Office of Health Promotion, Office of Sustainability, and Arboretum, to subsequent opportunities to present these issues to the City Wellness Committee, the City Resilience and Sustainability Committee, and to numerous local organizational meetings including the Charleston Resilience Network and Charleston Healthy Business Coalition.

Conducted in the summer of 2021, the research program data analysis is still underway, but multiple outcomes are already evident. Tangible organizational outcomes increase the attention and resilience to heat risks. The CMD integrated heat into their resilience plan and the City of Charleston explicitly incorporated heat into its new comprehensive plan, which will be overseen by the City's planning director, recently relocated from Las Vegas where the Guinn Center had emphasized similar challenges (Guinn Center, 2021).

The connection of heat to health reached into city committees with the Wellness committee reviewing proposals to assure health was considered in all policies. The City Sustainability and Resilience Committee supported heat risk inclusion in its future resilience planning. The Charleston Tours Association committed to providing water and training their tour guides about heat risks for unacclimated visitors. In collaboration

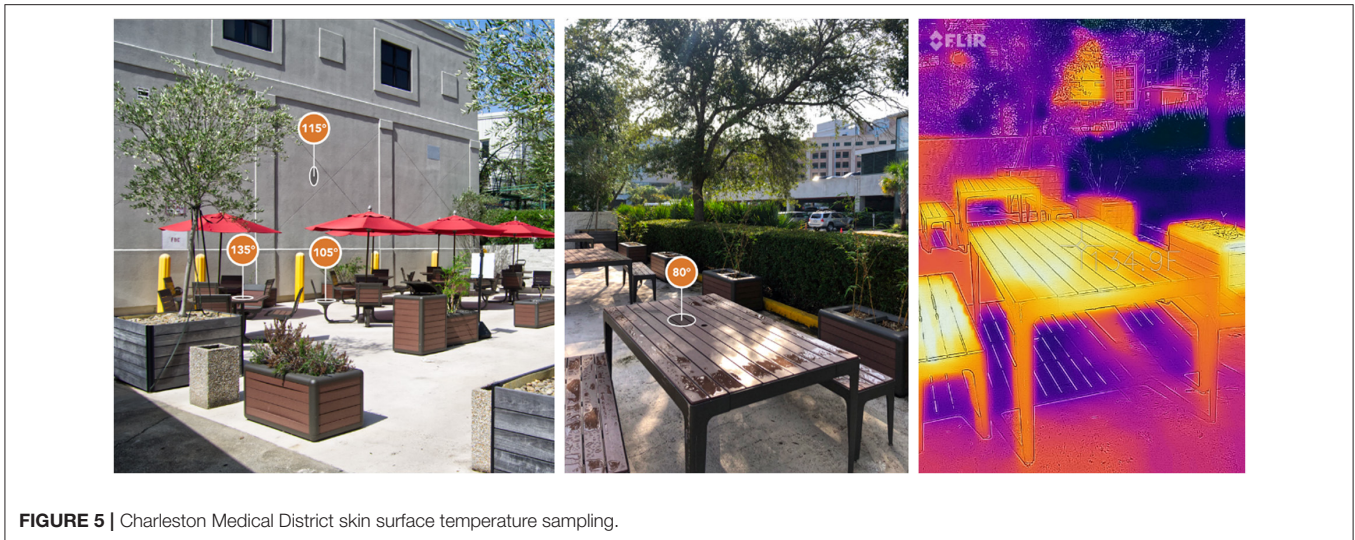


FIGURE 5 | Charleston Medical District skin surface temperature sampling.

with the city and the MUSC Office of Health Promotion, this group intends to fundraise for hydration stations for tourists and guides alike, which the City Parks Department agreed to locate in key park areas. The research using wearable sensors for outdoor workers in MUSC's Arboretum Grounds and Office of Public Safety, and in the Citadel Grounds team offered lessons that can be applied more broadly and promoted by the MUSC Office of Health Promotion. The South Carolina Department of Health and Environmental Control (SCDHEC) expressed interest in developing statewide programs on heat-health risks, coping resources and public health training, similar to the CISA Convergence of Climate-Health-Vulnerabilities web resource (CISA, Carolinas Integrated Sciences and Assessments, 2019a). Lastly, the City of Charleston is now paired with the City of Miami, the City of Phoenix, and the City of Las Vegas in a Bi-Regional Heat Research Initiative with pilot funding *via* NOAA/NIHHIS for the 2022 heat season.

Scaling up to a citywide effort fostered further connections among networks that reach around the state and connect to national efforts. These collaborations resulted in broader audiences hearing the message to consider water AND heat as the region considered climate adaptation. For example, the heat and health concerns resonated with South Carolina Interfaith Power and Light (SCIPL) already working on climate and energy poverty and brought their partners, South Carolina Chapter of Health Professionals for Climate Action (SCHPCA), into the conversation. CISA organizes the Carolinas Heat Health Coalition that includes representatives from CMD and multiple sectors and organizations around the Carolinas. The South Carolina Seven (SC7) program began addressing heat in its One Million Trees program, largely through the advocacy of the MUSC Office of Health Promotion. The MUSC Arboretum Board hosted a session to raise extreme heat awareness among its Board members and their networks. The Charleston Sierra Club invited the research team to present findings to the regional network of Sierra Club chapters. The Citadel presented the research at numerous conferences, including a student program

on lessons learned about extreme heat in Charleston. The University of South Carolina in collaboration with the City of Columbia received funding for the 2022 NIHHIS Heat Watch cohort. Through targeted collaborations with the Consortium for Climate Risk in the Urban Northeast, Regional Integrated Sciences Assessment (RISA) team, the City of Philadelphia adopted similar protocols to those of the Charleston effort, applied for the NIHHIS program, and joins Columbia in the 2022 Heat Watch cohort [National Integrated Heat Health Information System (NIHHIS), 2022].

LESSONS LEARNED, OUTCOMES AND PRACTICAL IMPLICATIONS

The work on heat and health in Charleston and in the region is still very much emergent as it continues to compete with flooding, the far more visible and growing hazard. However, it is now part of the local conversation, part of local planning, and grounded in locally relevant research and practical applications. For example, while Charleston hosted a tree ordinance for many years, that ordinance focused on protection of “grand trees,” not on their role in heat mitigation. It was only recently that Charleston clearly linked its work on tree canopy protection and expansion with this recent work on extreme heat by adding heat and equity considerations to their StreetTrees Storymap and in their tree canopy resources for residents (City of Charleston, 2020a, 2021a,b). Key lessons learned during this transformational process provide valuable insights for other areas where unintended hazard bias makes it exceedingly difficult to consider an all-hazards approach. These lessons illustrate multiple points to intervene in the processes reforming hazard bias.

Water AND Instead of OR

Although flooding continues to demand attention and resources due to its visibility in, and impact on, communities, and due to the inertia of systems such as disaster declarations, funding

pathways and technical expertise siloes, extreme heat now has resonance due to these types of collaborations (Keith et al., 2019). The efforts to date demonstrate that cities need not choose between addressing flooding and addressing extreme heat. Water AND heat deserve attention, and in some cases, the solutions to one benefit the other, which in turn allows cities to leverage federal or local funding more fully. Consideration of all hazards is an important criterion when determining capital spending priorities and so addressing multiple hazards with shared investments is simply a smart budgeting strategy.

Health Connections

The introduction of heat as a material risk only resonated once patient health risks were recognized. In the case of Charleston, patient wellbeing was the motivating factor for a transformative change. Engaging with health professionals who understand the epidemiological evidence of health risks associated with climate change, and the impacts of energy insecurity and its inequities on vulnerable populations, warrants greater effort from those working on climate change. For Charleston, this means examining community awareness of heat risk and reconsidering whether the heat warnings from the NWS are sufficient given community exposures, coping resources, and adaptive capacities. While Charleston adopted a Health in All Policies program, the operational approach to this as related to heat health inclusion is still to be determined.

Network Amplifiers

Individual efforts to heat-health risk extend the body of knowledge, but it is in the network amplification that true engagement resides. By starting with trusted relationships and working with various organizations and institutions, momentum built along the interest pathways of the various network actors. There is value in connecting multiple agendas while not attempting to corral those agendas into a singular pathway. The work in Charleston is not a project, but a system of mutually supportive connections that continues to evolve. Encouraging such evolution along interest-area pathways builds network diversity and robustness while drawing down boundaries and technical siloes. Diversity in turn invites in various new collaborations such as SCIPL outreach *via* its many ministries, MUSC outreach through physicians and patients, as well as through the Arboretum and the Sustainability office, which in turn connected to activities such as Heat Awareness Month, Earth Day, and tree planting events. Linking energy insecurity and the interests of SCDHEC expand the reach across the state.

Event Momentum

Heat Watch was an external validation of concerns and a community event that created new types of collaborators and conversations. Media outlets participated and a series of heat-related articles made the local newspaper, a Pulitzer-recognized press that previously focused on flooding. Local meteorologists began seeking out the opinions of physicians to guide evening forecasts. Due to its tripartite research program, the team was invited to participate in a nationwide conference of heat researchers, sponsored by the NOAA NIHHS program. Following that effort, multiple other organizers within NOAA

as well as the Southeast and Caribbean Disaster Resilience Partnership connected the team to heat researchers in other parts of the world, building and deepening the network and the ability to share best practices. Most importantly, following a joint announcement by NOAA and US Department of Human Health and Services at United Nations Framework Convention on Climate Change, 26th Conference of Parties (COP26), extreme heat has a national set of collaborations on similar trajectories of heat-health interface. *Via* this connection, the team encouraged NOAA and HHS to work more closely with FEMA and HUD to integrate heat risk planning in flood recovery where possible, and to explore the opportunity for federal recovery funds for heat waves.

These activities generated interest elsewhere. By presenting this work to SCOR and SCDHEC, these offices now intend to more fully engage and to integrate heat into the state resilience plan and into the statewide planning for health outreach. As mentioned earlier, the City of Columbia intends to somewhat replicate the program from Charleston, expanding impacts even further. For South Carolina, the opportunity to amplify this work statewide, engaging less resourced communities (which may act as proxies for energy insecure areas) into this growing collaboration is an obvious next step. In concert with recent NOAA satellite imagery improvements, the set of resources to do so is growing stronger.

Given the progress in such a short time period, it is clear that Charleston has the ability to overcome Hazard Bias, and to encourage its future investments to address heat mitigation and adaptation where possible. Drawing out discussions about heat-health risks alongside multi-benefit strategies with performance criteria tied to nature-based solutions is an obvious starting point. However, even with heat on Charleston's policy agenda, and with the additional resources provided by this research, addressing entrenched inequities in vulnerability requires more than just overcoming hazard bias, even if overcoming hazard bias is a necessary step.

CHALLENGES

There are certainly challenges to this work. For example, the network benefits from the dedication of a small group of constant participants who act as keystones while the overall web of actors grows stronger. Most of these keystones volunteer their time which is an inherent fragility, recognized by the network. The future of this coalition depends on these dedicated team members even as they seek to broaden participation and in turn network robustness. As this work is in the development of a system, and not a focus on a singular project, it remains critical for the team to not consider the work "done" once research findings are published, but to continue to engage and deepen community collaboration on the issue. Situating the work within state offices focused on resilience and health will be key to that growth, necessary, but not sufficient as heat is an inherently local hazard.

The limited funding for this research is dependent on federal dollars (*via* NOAA) even as federal recovery dollars (*via* FEMA/HUD) do not prioritize it. Moreover, federal disaster declarations have yet to introduce heat. And in the sultry South, even with South Carolina State Act 163 in place, flooding remains

a priority for funding, reinforcing technical siloes and sustaining hazard biases. Lastly while the SCOR intends to address heat, its legislatively mandated priorities, like its administrative oversight on recovery funding, are toward flooding.

Notably, none of these flood-related focal areas include health indicators, whether in the planning, implementation, or performance metrics. Without health as a criterion, the evaluation of success of any of these investments remains focused on capital assets, not people, and certainly not the most vulnerable.

Raising up heat health awareness and acting on it remains a challenge. While inclusion in the Comprehensive Plan is a notable step, the city lacks a Heat Adaptation Plan, offers limited awareness building and coping resources for near-term exposures (including providing no cooling centers), and struggles, like all small municipalities, with balancing budgets and needed investments. The coalition lacks the administrative powers to change this context and so continues to work at the margins, seeking collaborators with such powers to institute change.

Community members struggling the most with energy insecurity and with heat-health implications were not yet engaged in this research and so the reported disparate impacts herein lack the more nuanced understanding that a community engagement program could offer. Instead, the team reported on programs trying to provide relief services. While the patterns of vulnerability and need have become more apparent, it is not assured that resources will go to the historically marginalized and underserved communities. Achieving that goal will require design and implementation processes that focus on equity.

Lastly, while these research programs and deliberations continue, those who live with inherent risks due to energy insecurity need help now. The Southeast Energy Insecurity Stakeholder Initiative and various DHEC initiatives are seeking to address these issues (Duke University, 2022). The new federal emphasis on funding tied to heat health and environmental justice may offer the incentives to reduce/overcome hazard bias and pursue more inclusive (Water AND) strategies in adaptation (White House, 2021). Ultimately, addressing hazard bias requires those working on climate first acknowledge its pervasiveness and then act on rewiring the feedbacks that encourage such bias in pre-disaster mitigation, recovery spending, and adaptation planning.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

JB and KD made equal contributions to conceptualization and writing of this manuscript. Both authors contributed to the article and approved the submitted version.

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