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Disaster Recovery in Puerto Rico: Understanding Resilience Through the Island's Communities

DISSERTATION

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for the degree of

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in Urban and Environmental Planning and Policy

by

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DEDICATION

To my family, both blood and chosen, for their unconditional support, guidance, and love, especially those afar and those who have transcended the earthy plane. To my wife Mónica and my son Mikael, for making so many sacrifices, many more than I care to admit, so that I could follow and achieve my dreams.

Finally, this dissertation is dedicated to the community aqueducts for trusting me with their stories and so generously opening their houses and hearts.

"The memory of our pain deserves to be appreciated, remembered, and never denied."
—Oscar López Rivera, March 12, 1997

"...Mi próximo recuerdo fue ver las fotos y vídeos de la devastación, los cadáveres flotando. Estaba en medio de la orientación del doctorado, que apenas comenzaba. Necesitaba salir de allí, necesitaba irme. No sabía a donde ir. A penas llevaba viviendo un mes en California. Sentía que cuando más la isla y mi familia me necesitaron, más lejos estaba. Lo sentí en lo más profundo de mi ser. Lo hable con Mónica, me quería ir, pero ella me decía que no había nada que hacer en aquellos momentos, que sería una carga innecesaria para mi familia. Yo quería ir a Puerto Rico, ayudar a los míos. En los primeros días después de María no salían ni llegaban vuelos a la isla, o al menos eso decían las aerolíneas. Creo que ha sido el único momento que quise dejar el doctorado. Mónica me recordó como el doctorado podía ser una herramienta para ayudar a los míos, aunque no lo pudiera ver en aquellos días."

—Omar Pérez Figueroa, Septiembre 20, 2017 (four days after Hurricane María)

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT OF THE DISSERTATION

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by

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Doctor of Philosophy in Urban and Environmental Planning

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The Caribbean faces numerous natural hazards, including hurricanes and earthquakes. Relative to most countries, Caribbean nations experience disproportionately higher impacts of these events in terms of fatalities and damages. Puerto Rico's experience is not different from other islands in the Caribbean, but its limitation on political and economic power has resulted in local and federal government recovery efforts being very slow and limited at best. As a result, communities on the island have created the conditions to recover from these events by creating collective strategies, to access essential resources, e.g., water, food, and medicine.

This dissertation centers around the experiences of communities in Puerto Rico under cascading disasters (e.g., storms, earthquakes, COVID-19 pandemic). It follows a mixed-methods approach that investigates how disaster resilience needs to incorporate the goals of environmental equity community empowerment under climate change conditions. It pays special attention to water governance issues within these foci, as it intersects communication, collective action, and governance.

This dissertation used three different research designs to investigate how resilience mechanisms and processes play out on community members and stakeholders in Puerto Rico. In the first study, I used a text analysis approach to discuss how communities can impact disaster recovery through social media communication. This chapter reflected how people use Twitter under disaster conditions. In the second study, I employed a survey including two regression models to generate discussion about the resource mobilization capacity of Puerto Rico's small water systems under disasters. For the third and final study, I used a qualitative approach, including non-structured interviews and an ethnographic approach to Puerto Rico's community aqueducts volunteers and personnel. This last study aims to identify diverse understandings of resilience and the role of water in operationalizing it.

The findings indicate the importance of inclusion and community empowerment in creating strategies and understandings of resilience that can help communities to recover. The first study revealed social media's importance when traditional communication channels fail to convey critical information. Additional to social media, social networks play a crucial role in accessing resources resulting in shorter recovery time for communities. Finally, all studies underscore the importance of accessing drinking water under disaster conditions and how it can serve as a vehicle to study how communities stressed by social and environmental conditions recover after a disaster.

This research gave the opportunity for those voices most impacted by disasters to be included, revealing several and complicating issues about resilience for decision-makers to consider. In addition, the findings provide a groundwork for assessing interventions to improve disaster recovery strategies for historically marginalized communities.

CHAPTER 1: INTRODUCTION

> *"How should I say this…thanks to these groups of people, the government freed itself from a lot of responsibility—while the government figured out how to help their residents, these communities have already made up for their losses by helping each other. Look, I am telling you, we reinvented ourselves; we came up with innovative ways of managing the crisis; we even came up with a way of getting water from this small creek. The truth is that without these communities, the government would not exist. I believe people would have revolved; a civil war would have taken place. Because good or bad, community aqueducts do so much more than the government"* (CommunityAqueduct_4)

Alicia's[1] story is not unusual among residents in Puerto Rico. Recently, islanders have experienced several disasters, including Hurricane Irma and Maria in 2017, the 2020 earthquake events, and the COVID-19 pandemic. These events, coupled with government austerity measures resulting in cuts to pensions, education, and health services (Tormos-Aponte et al., 2021), have aggravated the island's dire economic conditions[2]. These disasters have also severely impacted the island's social wellbeing, increasing loss of life, housing insecurity, and high energy costs. Alicia's quote highlights the roles of the island's communities, in managing and coping with catastrophes, especially after Hurricane Maria. It also emphasizes the importance of accessing drinking water to manage disasters. Groups that have supported the island community's recovery process include CAM (Centers for Mutual Aid*,* in English) and community aqueducts. Alicia calls attention to the fact that communities can become self-reliant when governments cannot manage disaster conditions (Allen & Peñaloza, 2017) by independently accessing water, creating power grids, or cultivating food. Even when the quote does not explicitly question which factors can impact state capacity and response, scholarship underlines the role of social, political, economic, and societal factors in the recovery process.

[1] Alicia is fictional name used to preserve the participant anonymity

[2] Puerto Rico has been experiencing an economic depression since 2006 (Caraballo-Cueto & Lara, 2017)

In reviewing the literature on resilience, my conception of the subject is a synthesis of research that examines social learning, the ability to bounce forward, and the ability to question the current socio-political model. This definition recognizes resilience as a group of practices and a paradigm that acknowledges collective care as acts of resistance to disconnection, marginalization, and internalized oppression (Pyles, 2018).

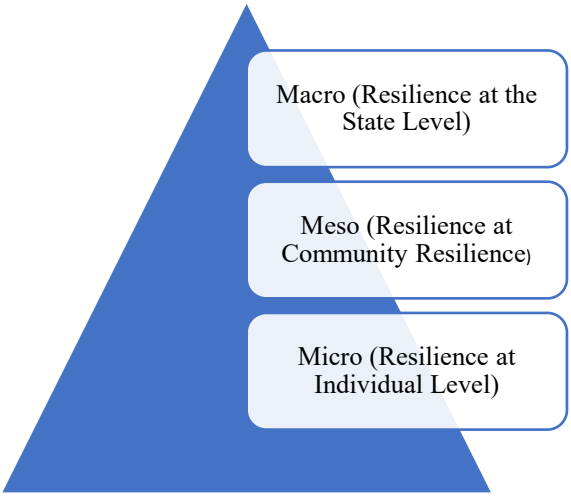
We know from research that one-way resilience has been incorporated into communities has been through water systems (Boltz et al., 2019). Water is critical in guiding the trajectories and boundaries of human development. Furthermore, Boltz et al. (2019) argue that water is key to unlocking the complex challenge of designing and managing the resilience of coupled human-natural systems[3]. Building resilience in the water sector highlights the importance of improving water security under climate change conditions and reducing water-related risks and hazards (Rodina, 2019).

Under these circumstances, I am interested in investigating how effective disaster resilience needs to incorporate the goals of environmental equity and community empowerment under our current climate change context. This research focus is particularly salient given that not only historically underrepresented communities are the hardest hit during disasters but that the Caribbean and Puerto Rico provide critical insights toward the interpretation of how communities cope with disasters when they have limited resources. Consequently, this research is centered on various disaster experiences in Puerto Rico, an island in the Caribbean whose impact of disasters has been disproportionately large compared to neighboring regions (López-Marrero & Wisner, 2012).

[3] Interactions between human systems (e.g., economic, social) and natural system (e.g., (e.g., hydrologic, atmospheric, biological, geological)

This dissertation looks at resilience across different spatial scales of analysis (Figure 1). It follows a “three article” approach, each of the chapters analyzing a different level in which resilience takes place (micro, meso, macro) For example, chapter two looks at the individual level of resilience, it is at this level where we can observe how users can build their resilience by the kind of information, they are able to access . In addition, Chapters three and four analyze resilience from the community perspective (meso level), including implications for the macro level of analysis. Also, in looking at resilience at different spatial scales, I examine resilience from a less critical approach to a more critical approach. A less critical approach to resilience is define as "what communities undertake to manage an extreme event". Differently, a more critical approach illuminates what it means to be resilient and allows communities on the ground experiencing hazardous conditions to define it in their own term.

Figure 1. Spatial Scales of Analysis



This dissertation comprises three articles, an introduction and a conclusion that collectively follow a mixed-methods approach, each exploring different methods. These methods include (a)social medial content analysis, (b) regression models, and an ethnographic approach to community aqueduct users and operators from twelve communities. A mixed-methods approach

is critical for this study, as it allows me to obtain data at a larger scale to observe general trends of resilience in Puerto Rico and its community aqueducts. It also allows one to obtain more granular data to observe what is happening on the ground. By employing this mixed-methods approach, this study seeks to understand how and why communities deal with water governance and disaster resilience issues by looking at social media's collective functions during disasters and observing community aqueducts' mobilization under disaster conditions.

While social media analysis uses Twitter data to understand how diverse stakeholders employed social media under Hurricane Maria, the statistical models use data from a survey on the community aqueducts' characteristics under disaster conditions. Finally, the ethnographic approach follows community aqueduct day-to-day practices to understand their challenges related to water use and resilience.

Research Questions and Study Themes

The three papers in this dissertation seek to understand how diverse communities in Puerto Rico cope and understand extreme weather events, such as hurricanes. This research is driven by the overarching research question: how collective mobilization serves as a vehicle to manage hazards and access vital resources, mainly when those communities have limited resources and political power. Each paper addresses this question by answering similar questions such as:

1) How can social media communication be harnessed to engage and mobilize citizens effectively?
2) What is the impact of resource mobilization on disaster resilience and water governance?
3) How are diverse framings of resilience shaping community aqueducts' disaster recovery efforts, and what is the role of water issues in operationalizing resilience for community aqueducts?

The first question is answered by employing a content analysis approach on 2315 Tweets related to Hurricane Maria. Tweets were collected from September 16 and November 7, 2017, using a random 1% random sample approach. This method of collecting a 1% random sample has proven to be representative of the Twitter database. Messages were retrieved by keywords, geographical boundaries, and user ID. I used a deductive content analysis with a functional framework to analyze these tweets. This framework presents fifteen prospective roles for social media under disaster conditions varying from receiving disaster preparedness information to expressing emotions. This first article looks at Twitter and how it can be used as a proxy to look at online collective mobilization. I saw that the social media tool was mainly used to find out news about the events, express positive and negative emotions, and understand the social-political and scientific causes of the event. Initially, this paper set out to capture its use by islanders in the aftermath of Hurricane Maria. However, two factors challenged my original approach—first, the hurricane knocked out the power grid, limiting the potential sample size of messages from Puerto Rico. The second factor resulted from the Twitter API[4], which limited the number of tweets I retrieved coming from Puerto Rico. As a result, I expanded my sample by including tweets from the U.S. The paper argued how important it is to understand the ways social media is employed during and after a catastrophe and how it can help promote more effective planning and recovery, as well as underscoring the ways diverse stakeholders understand and manage disasters. Most importantly, this article suggests several extensions of the functional framework for disaster events—for example, the importance of sound/effective risk communication and messaging in the pre-event phase of the event.

[4] Application programming interface, is how software applications talk to each other using the Internet

The second research question was answered by employing a survey of registered community aqueducts (n=39) in Puerto Rico. This survey focuses on how communities mobilize and recover after hurricanes Irma and Maria and the earthquake events of 2020. Questions from the survey were answered by community aqueduct personnel, including volunteers, paid personnel, and water operators. I used two Ordinary Least Square (OLS) models to analyze the survey that identified and evaluated elements that provide resource mobilization to community aqueducts. Community aqueducts are also known as non-PRASA because they fall outside the island's only public water utility, Puerto Ricos Aqueduct and Sewer Agency (PRASA). These communities are typically located in rural areas and often provided the only means for residents to access clean water after Hurricane María. These communities created their water supply infrastructure, including primary and, in some cases, secondary treatment processes. Conservative estimates state that these communities have over 100,000 active users[5]. Unfortunately, local officials sometimes see non-PRASA systems as primitive, ineffective, and unsafe (Arce-Nazario, 2018). While some of these systems predate the 1980s, they became more visible after Hurricane María as a sustainable way to ensure that the water supply did not depend on the crippled infrastructure of PRASA. This paper examines how community aqueducts can mobilize their community under cascading disasters using resource mobilization theory. The second article looks at how community aqueducts can build social capacity and allocate resources to cope with disasters and access clean drinking water. My OLS models first looked at the characteristic that affected resource mobilization and second, which variables impacted the recovery process of community aqueducts. My first model highlights how funds obtained after Hurricane Maria, social networks, community participation, total faith-based institutions, and the

[5] This number is an approximation; it fluctuates pre- and post-Hurricane María and is affected by migration.

percentage of women who collaborated with the aqueduct increased its resource mobilization capacity. My second model underscores that networks and decision-making approach positively impact an aqueduct's recovery time by reducing it.

The third research question was answered using unstructured interviews with diverse stakeholders (n=36) collaborating with community aqueducts and an ethnographic approach to twelve community aqueducts. This qualitative approach emerged as a result of a community-based research approach (CBR), whose main objective is to involve community members in the design and implementation of research projects. The ethnographic approach was conducted through CBR, including partnering with a grassroots organization that worked with rural communities in Puerto Rico, including community aqueducts. Because the focus of the third question was to explore diverse understandings of resilience, I interviewed a series of stakeholders, including government officials, non-governmental organizations and technical organizations personnel, and community aqueducts workers and staff. Data collected under this approach included more than 100 hours of work, including conversations, community visits, phone calls, and workshops for community aqueducts. For this article, I focus on the diverse understandings of resilience for collaborators working with non-PRASA systems. I also focus on how water issues serve as a vehicle for the operationalization of resilience. Although there is literature that defines what resilience is, there is still little known evidence about the implications of those understandings for strategies and actions leading to resilience outcomes. While this distinction may seem trivial, it is not. For example, if we understand resilience as those strategies that allow communities to return to the previous state without interrogating those conditions, we may perpetuate unjust conditions. My data findings underscore the implications of understanding resilience as both an outcome and a process that fortifies communities from the impacts of

disasters. For instance, looking at resilience as an outcome frames resilience in very mechanistic ways that, in some instances, can overlook the role of communities and their impact on managing disaster events. Unlike the outcome approach, looking at resilience as a process allows the emergence of alternative frames used by community members to understand resilience—these alternative frames focus on equity and justice as part of a community's resilience and survival.

While resilience and disaster recovery are interrelated, they are based on different assumptions. Disaster recovery focuses on how well or poorly a society can return to normality or pre-disaster conditions following an extreme event. On the contrary, resilience arises from the discussion of whether a society has the characteristics to fortify it from a profound impact on people and their livelihoods. Furthermore, resilience goes beyond simply restoring normal operations; it provides the bases to observe the specific mechanisms by which disaster impacts are both reduced and recovery enhanced. Thus, when I refer to resilience in the dissertation, I am interested in the actions, mechanisms, and characteristics that community members employ to address disaster impacts. By understanding these mechanisms and actions, we can design better policies that are attuned to communities' needs in becoming resilient. Better policies emerge, when they are both more inclusive and more democratic towards communities.

While the term is highly contested, its principles have been included in different international policy instruments, such as the United Nations International Strategy for Disaster Reduction (UNISDR), the 2015 Sendai Framework, and the 2005 Hyogo Framework (Cutter, 2016). These frameworks are used internationally as a way to guide policies to reduce disaster impact and increase societies coping capacity for extreme events. They are not employed only by international organizations but also by private organizations, including state and local

governments. As such, it is critical to understand how institutions defining resilience; depending on its application and how it is operationalized, it can leave communities out of the decision-making processes dealing with communities' resilience. Ensuring that communities are included in these processes can strengthen the policies aimed to help them. To sum, I employ the term because of its potential for creating policies to improve societies' management capacities to face climate and extreme weather events.

In looking at the concept resilience, different scholars use it as a dependent (outcome) and independent variable (process), dependent on the spatial level of analysis (Asadzadeh et al., 2017). Resilience as an outcome is mainly used as a dependent variable by policymakers and other fields that define how external variables can affect individuals' and communities' capacity to recover, for example, previous social vulnerabilities. A critique of this approach is that it has left out arguments that underscore how disasters are not only caused by the magnitude of the events but also by systems of oppression like colonialism.

While the discussion about the merits of using resilience as an outcome, process, or both continues to get traction, there is less discussion on how the spatial scales used analyze resilience can interact with each other or what are the characteristics that influence them (McManus et al. 2012; Boon 2014). Attempts to understand resilience need to look across scales (macro, meso, micro); understanding this is critical as each scale looks at a different component and characteristics of how and why resilience occurs (Cutter, 2016).

The Caribbean and Puerto Rico: A Case of Disaster Recovery

Compared with other geographical regions, the Caribbean is more vulnerable to disasters in terms of damage to gross domestic product (GDP), disaster frequency, and affected population. For example, Otker-Robe, (2019) underscores how large sectors of the Caribbean

population live in high-risk areas exposed to sea-level rise and poor infrastructure. Because of heavy reliance on weather-sensitive sectors such as tourism or agriculture, the risks are expected to worsen. These damages include damage to biodiversity, coastal erosion, food, and water security, which increases people's health risks (Otker-Robe, 2019). According to Srinivasan et al. (2017), many Caribbean islands are among the 25 most vulnerable nations regarding disasters impact per capita or land area. For some of these islands, the economic consequences of disasters will surpass that of their GDP. For example, the 2017 Atlantic hurricane season was the most active in modern history, with a loss of US$294.92 billion and approximately 10,000 human lives. From that total, the Caribbean was the region hardest hit, with damages estimated at around US$165 billion and 8,000 lives lost.

Similarly, Jamaica, Cuba, Puerto Rico, and the U.S. Virgin Islands experienced high earthquake activity from late 2019 to early 2020, causing damage to physical structures that were already weakened by previous storms. For the Caribbean communities, finding ways to cope, prepare, and manage disasters associated with environmental hazards is not only essential but critical for their survival and overall well-being.

The Caribbean region is exposed to multiple environmental hazards due to its geographic position. Events such as hurricanes, floods, landslides, earthquakes, and volcanoes cause loss of life and property, disruption of livelihood, and, in some cases, erasing years of development (López-Marrero & Wisner, 2012). Nevertheless, historically, the Caribbean has been overlooked in disaster research as a critical geographical area to understand how communities can take control of their recovery process (Kelman et al., 2011) to reduce mortality and improve disaster management practices. Today, both the media and scientific communities pay special attention to it for both the impact it sustains from disasters and its remarkable capacity for resilience.

Puerto Rico has confronted an economic and fiscal crisis since 2006, which has resulted in 45 percent of the population living below poverty levels, with high levels of welfare dependency, and a population decrease of 500,000 over the past ten years primarily due to limited employment opportunities (Caraballo-Cueto & Lara, 2017) . Furthermore, the island has been in recession for the last 11 years (Gillespie, 2017; Caraballo-Cueto & Lara, 2017), and its debts and physical infrastructure continue to plummet (Yglesias, 2016).

Puerto Rico represents an important case to study how disaster resilience and water governance look when an island lacks the political power to execute effective disaster policies. To understand the complex political context of Puerto Rico, we need to know how colonial dynamics have shaped the island. Its political context serves as the backbone for understanding how its disaster policies were designed. The circumstances that made the island first a Spanish possession and then a colony of the United States created the conditions that have transformed the island's built environment to support colonial interests while impacting the island's landscape and ecology (Atiles-Osoria, 2014).

While the case of Puerto Rico is unique, their communities' capacity for mobilizing and triggering change within and outside state government structures looks like other societies, especially in the global south. Similar to other societies in the Caribbean, Puerto Rico's government system is built on top of the genocide of indigenous people, the enslavement of Africans, and the continuous exploitation of land, people, and animals (Lloréns, 2018). High levels of poverty, limited state capacity for recovery, and dependence on foreign capital, among others, are part of the exploitation legacy in the Caribbean. These conditions have disproportionately impacted historically underrepresented communities in this region. As a result, previous socioeconomic and racial inequalities directly shape their recovery capability

during these events (López-Marrero & Wisner, 2012). This argument underscores how environmental justice issues can intensify the impact of hazards and disasters (Garcia-López, 2018). This is one critical component of my case study that could benefit other places where disasters can heighten EJ issues. Moreover, Puerto Rico's communities' capacity to work outside state structures underscores how historically marginalized societies have forced the needed change when precisely those structures of power have denied them their right to live under just conditions.

Its case is unique even when Puerto Rico shares a historical context with other neighboring islands. The repeal of section 936[6] coincided with the global recession, which devastated the island's fragile economy (Lloréns, 2018). During these years, the local government tried to aquire other sources of capital by changing their zoning laws to allow more development on the coasts and previously protected land. Change in zoning resulted in the destruction of mangroves and high pollution levels, creating new environmental justice issues[7]. In addition, these conditions are compounded by the implementation of federal policies. U.S. policies constrain Puerto Rico's disaster policy—every polity has some, even if minor, influence or control. The U.S influence affects Puerto Rico's sovereignty, affecting the equitable outcomes from set policies. Specific policies of the United States exemplify this argument. For instance, in 2016, President Obama and the United States Senate signed the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA), a bill that would allow Puerto Rico to file for bankruptcy. This law created an oversight fiscal control board administering Puerto

[6] Section 936 of the federal tax code allowed subsidiaries of U.S. firms operating in Puerto Rico to pay no federal taxes on their Puerto Rican profits. This tax code allows the establishment of many foreign industries of the island, who boosted the island economy by providing jobs and salaried to island residents

[7] These included the Proposal of gas pipe over an aquifer and a natural protected area, mining of protected areas, and the construction of an incinerator near a poor community.

Rico's finances, whose primary mandate is to restructure the debt and pay back bondholders. To restructure the "debt[8]," PROMESA has defunded Puerto Rico's education, health, and recovery agencies. As a result, when Hurricane María hit the island, the local agencies had minimal capacity to manage disaster-related tasks. This lack of capacity, compounded with the event's magnitude, resulted in the death of more than 3,000 people (Sosa-Pascual et al., 2018; Camploy et al., 2018; Robles et al., 2017; Kishore et al., 2018; Santos-Burgoa et al., 2018).

Even under these fatal conditions and limitations in implementing recovery strategies, many groups, including those led by women, activists, and grassroots organizations, have conducted relief actions for the island. Slow responses from agencies to provide water, food, shelter, and medicine in the mountain regions[9] triggered various self-help and solidarity efforts in isolated communities. The actions that communities took to increase collective efficacy later resulted in the founding of more formal entities that served as drivers of local reconstruction efforts. One such organization is the Centros de Apoyo Mutuo[10] (Delgado, 2018; Dols, 2017), which helps facilitate the distribution of emergency resources. Borges-Méndez and Caron (2019) argue that Puerto Rican communities and local actors demonstrate their capacity to create political spaces for collective action to promote self-reliance in disaster contexts and with insufficient material resources. They further state:

> "*…In these political spaces, communities and women spoke directly to the collective goal of breaking away from the cycles of dependency on external knowledge (or political patronage) while asserting skepticism about reconstruction strategies and mechanisms that do not question the 'previous state' of neglect and economic exclusion that is well documented in regional poverty and unemployment data and the physical deterioration of the built environment*." (p. 11)

[8] Some sectors of Puerto Rican society argue that it is an illegal debt because it has not been audited. This could mean that some of this debt could have been emitted illegally (Acevedo, 2019).
[9] This is where most coffee-producing communities are located.
[10] Centers of Self-Help Assistance.

In sum, Puerto Rico presents a critical case for understanding community resilience within the Caribbean because the island lacks political and economic power to implement effective disaster policies. Puerto Rico's context (e.g., declining economy, dependence on a metropolis, delayed government recovery efforts) is not uniquely different from other Caribbean islands. However, its robust social capital and aid networks have allowed its people to implement recovery practices when the government fails to provide them (Pijawka et al., 2020; Roque et al., 2020). For instance, residents of low-income Puerto Rico have described how mutual aid and solidarity among community members in times of crisis like flash floods are sources of support shortly before, during, and after such events (López-Marrero, 2010).

COVID-19 Limitations

It is crucial to note that an essential part of the data collection process occurred in 2021 when the pandemic related to COVID-19 was still occurring. As the pandemic continued, I had to start my interviews over Zoom and follow up in some cases by phone. In-person interviews and visits were conducted in the summer of 2021, when the University of California had resumed research practices. The pandemic also forced me to develop creative ways of accessing data, such as using social media platforms (Facebook and Twitter) to follow community aqueducts' day-to-day activities and challenges. At times, the pandemic presented challenges, especially for the ethnographic approach; still, I was able to travel every three months to Puerto Rico to finalize my data collection process.

This dissertation includes various limitations; still, they point out future venues to extend my research. One limitation was my status as a volunteer with the Bosque Modelo. While it allowed me to enter the field and access community aqueducts and other stakeholders working with them, it was also limited because I only worked within the organization's geographical

scope. While there are 77 community aqueducts out of the 241 within the geographical scope of the Bosque Modelo, there are many aqueducts outside this region that I could not access or whose users I was able to interview. Also, because I was traveling every three months to collect the data and interview people, it limited who was available for the interview at the time of my visit. To address these particular issues, I was able to hire and train a graduate student to help me collect the data in compliance with IRB regulations. However, using the survey instrument, I collected data beyond the geographical scope of the Bosque Modelo. In the future, I plan to extend my ethnographic approach beyond the geographical scope of the Bosque Modelo to observe if there is any variation. Finally, future considerations working with community aqueducts should include climate change impacts, as they are very likely to experience long drought periods and future storm events.

Implications and Contributions

This research has two broad implications. First, it forces us to rethink how we understand resilience under disaster conditions, especially in a context in which its communities have been historically marginalized, have limited political power, and can still mobilize to recover from an extreme event (e.g., storms, earthquakes). The second significant contribution has to do with the role of water governance in disaster resilience. Recent critical water crises such as those in California and South Africa strongly indicate that current water systems are not resilient to the combined urbanization process, governance challenges, and climate change impacts (Rodina, 2018). As a result, any consideration of resilience must consider water governance as an essential element in managing future challenges regarding interactions between environmental-human systems. It also must include those communities that have been historically marginalized in designing and supporting the implementation of recovery policies and practices.

My first article holds a broad understanding of how social media, specifically Twitter, can be used to increase communities' disaster resilience. It notes how social media has been used when communities impacted by disasters have limited communication and are remote, as is the case of Puerto Rico. Additionally, this research underscores the importance of the pre-event phase of an upcoming environmental hazard, especially for disaster managers communicating vital information. Similar to my first article, the third paper invites the reader to explore further dimensions of resilience by including divergent understandings of what it means to be resilient under disaster conditions, especially those communing from community aqueducts. In the same way, this paper brings a critical perspective on how we understand resilience by mobilizing political-ecology literature. This literature highlight issues of social justice and equity in the way we conceptualize resilience, water use, and its consequences for designing recovery strategies. Also, it underscores how policy officials can perpetuate inequalities by overlooking communities' previous conditions and focusing only on bringing communities 'back' to their previous state. In addition, paper three brings forward the importance of water issues in looking at how resilience is operationalized. Also, this third writing piece is particularly salient given that there is no agreement on operationalizing resilience (Davoudi et al., 2012) and that the literature pointing out the role of water governance in this process is limited (Rodina, 2018). Still, my findings revealed how water issues could serve as a vehicle for mobilization and organization, further triggering water conservation and community-building processes that ultimately lead to resilience strategies. This same model can potentially be applied to other communities in the same context as those in Puerto Rico.

The second paper emphasizes the role of collective mobilization and participation in community aqueducts in Puerto Rico. This research adds to the literature that highlights how

social capital and social networks are critical in obtaining essential resources (Aldrich, 2012, Roque et al., 2020). This was particularly true for communities accessing clean drinking water through the community aqueduct water grid in the aftermath of Hurricanes Maria and Irma. It was observed that participation was the most critical factor for resource mobilization. This brings implications for policy creation that include and support spaces for community building. Finally, decision-making was also essential in having a shorter recovery time—highlighting the importance of democracy and equitable participation in improving the recovery time for affected communities.

However, the most crucial aim of this research is to produce further investigations that would assist communities in Puerto Rico and under a similar context to build their resilience and be prepared for the subsequent hazards as they will become more frequent under climate change conditions. Finally, the government has proven to have a limited capacity to respond under disaster conditions, therefore is critical for the communities that will continue to be affected by extreme weather events and environmental hazards to recognize their power and resources in managing them. However, this does not mean that government should do less to help these communities but rather the opposite.

CHAPTER 2: ONLINE STAKEHOLDER PARTICIPATION DURING HURRICANE MARIA

Introduction

As a result of climate change altering global temperatures and hydrological patterns, conditions related to existing environmental hazards will continue to exacerbate the likelihood of extreme events like floods, droughts, hurricanes, and wildfires (Sheffield and Landrigan, 2011; Intergovernmental Panel on Climate Change, 2018; Watts et al., 2019). These environmental hazards can quickly turn into disasters if they surpass pre-expected thresholds of human death, economic losses, and other costs (Smith, 2013). Notably, low-income and underrepresented communities have more difficulty recovering from disasters than higher-income communities. These low-income communities become vulnerable when their characteristics affect their ability to avert, recover from, and cope with environmental hazards (Wisner et al., 2004; Macias et al., 2021). Thus, anticipated changes in hazard frequency and intensity are likely to have disproportionate impacts on environmental justice communities.

Social media plays a vital role in communication during disaster response (Sutton et al., 2014; Takahashi, Tandoc and Carmichael, 2015; Kim and Hastak, 2018). As a communication tool, social media allows people to communicate and share messages and resources in real-time (Lindsay, 2011; Kim and Hastak, 2018). Increasingly, social media plays a significant role in disseminating disaster information by allowing people to share information and ask for help (Velev and Zlateva, 2012; Tsao *et al.*, 2021). Social media offers a rapid and wide-reaching form of communication not only within affected areas but also between affected areas and the rest of the world (Takahashi, Tandoc, and Carmichael, 2015, p. 392). Following a disaster event like an earthquake, the usage of social media through mobile phones and emails increases and surpasses traditional communication methods like phones (Muralidharan et al., 2011; Velev and Zlateva,

2012). For example, more than 20 million people tweeted about Hurricane Sandy during the event (Guskin, 2012). This new communication trend has fostered a perceived legitimacy of social media during disasters (Murthy and Longwell, 2013; Feldman et al., 2016). Public expectations are changing, affecting governance as well– even emergency managers now use social media platforms in disaster response; each year, more and more people are enrolling in electronic alert notification systems (Wendling, Radisch and Jacobzone, 2013).

Social media as a disaster communication platform allows users to both consume and distribute (re-share) disaster messages. The medium can rapidly adapt to real-time situations and needs. Social media has adaptability characteristics that allow for communication between residents impacted and multiple stakeholders and agencies responding (Murthy and Gross, 2017).

Social media use has increasingly turned mainstream among public citizens (Pew Research Center, 2019), especially for disaster response (Sutton, Fischer, *et al.*, 2020; Renshaw *et al.*, 2021). Therefore, there is a need to better understand how social media communication can be harnessed to engage and mobilize citizens and lessen public health burdens effectively. Social media can be used in various ways across different phases of disaster planning and response, from amplifying coverage of a pending disaster to sustaining coverage post-event to motivate assistance, resources, and donations, to connecting loved ones and networks (Vieweg *et al.*, 2010). It can also be used by diverse actors, from individuals to government agencies to community organizations. At the individual level, social media enables individuals to share information, mark themselves as safe following an event, or ensure that resources are available to those who need them (Lindsay, 2011). At the organizational level, emergency planning and

response organizations draw on social media as an emergency management tool for disseminating emergency communication and warnings (Sutton *et al.*, 2014).

A functional approach to understanding disaster communication describes how social media may be used during disasters in real-time. It can also inform how governments and public health agencies may leverage social media for future pending disasters. Houston et al. (2015) present a functional framework for social media disaster communication that captures the various ways social media may potentially be used before, during, and after a disaster. The framework presents 15 potential "functions" for disaster social media, ranging from providing and receiving disaster preparedness information to expressing emotions, concerns, and well-wishes. It aims to understand who the users of social media are.

Because the functional framework draws mainly from literature review, it is important to understand whether and how the framework describes an actual disaster situation will help refine the framework for particular geographies and types of hazards, lending to its external validity. This paper presents an empirical application of the Houston et al. (2015) functional framework, using the case of Twitter use during and after Hurricane María. We draw on a deductive content analysis of Tweets shared about Hurricane María to identify the ways in which Twitter was used and by whom during and after six weeks post-Hurricane María landfall. Understanding how individuals use Twitter during disasters and in the immediate aftermath will be important as hurricanes occur more frequently and the public continues to turn to social media as a mainstream news source. Public health and disaster response organizations will benefit from a more detailed understanding of who and how communication on social media can play a role in mitigating the public health burdens that result from disaster events (Sutton, Fischer, *et al.*, 2020).

Case Context: Twitter as a key platform for disaster response

Among social media platforms, Twitter has emerged as a pivotal medium for sending messages about what is happening on the ground during disasters (Sreenivasan, Lee and Goh, 2011). Thanks to Twitter's low-bandwidth feature, individuals can send out messages with limited internet access or when there is network congestion (Li and Rao, 2010; Nguyen, Kawamura and Ohsuga, 2013). Also, Twitter has the potential to quickly broadcast the content of a local event to a bigger audience. For example, the 2008 Mumbai bombing and the 2010 crash of US Airways Flight 1549 highlighted a reduction in viewing traditional media and a coincident increase of traditional media sources sharing news on Twitter (Murthy, 2011). While Twitter can increase the visibility of an event, online language production can be affected by the character limit constraints of the medium, which can impact the way people interpret messages (Boot et al., 2019).

Although Twitter has proven to be a valuable tool for risk communication during a disaster, this medium is still not used by everyone. Twitter was released in 2006, and today it has more than 330 million monthly active Twitter users, with 69.3 million users in the U.S. (Statista, 2020); this is approximately 25% of the total US population, including Puerto Rico. Although people in disaster conditions highly utilize Twitter, it does not mean everyone has equal access to this platform. Available demographics indicate that the largest age demographic of Twitter users ranges from 25 to 34 year-olds and have, on average more education than U.S. adults overall (Duggan and Smith, 2013; Duggan et al.,, 2013; Blank, 2017). Additionally, approximately 42% of adult Twitter users have at least a bachelor's degree – 11 percentage points higher than the overall share of the public with this level of education (31%) (Pew Research Center, 2019). This implies a socio-economic digital divide. Thus, policymakers and disaster respondents should

approach Twitter with caution since its potential as a communication tool to reach the masses can be biased.

Case Background: Hurricane María

The 2017 hurricane season was among the most active in recent U.S. history. Hurricanes María, Harvey, and Irma left swaths of the United States and the Caribbean devastated (Rios et al., 2020). On September 20, 2017, Hurricane María, a category four hurricane, struck the island of Puerto Rico. The hurricane contained sustained winds of 145 mph, peaking at 155 when landing on the island, and leaving around 37.9 inches (962.7 mm) of rainfall (Pasch et al, 2019). Between 60,000 and 90,000 houses were destroyed and an additional 250,000 partially damaged (Meléndez and Severino, 2018). At least 70,000 people were displaced, and around 135,000 left the island (Meléndez and Severino, 2018). María is the worst hurricane the island has experienced economically and by loss of life since Hurricane San Ciriaco (category four) in 1899, which was the first hurricane Puerto Rico experienced after U.S. colonization in 1898 (Schwartz, 2016). It also forced many islanders to leave in the hurricane's aftermath (Macias et al., 2021).

Hurricane María devastated the island, leaving it in a complete blackout for several months (Criss, 2018; García, 2021). Four years have passed since the hurricane, and the crises have only compounded. The island power grid continues to function in a precarious state; some sectors of the island waited a year for their power to return (Sanchez, 2018; García, 2021). The total economic losses for the island were estimated at $90 billion (Esquerdo, 2018; García, 2021). Furthermore, FEMA denied around 62% of aid applications, including 80% of aid appeals (Acevedo, 2018; García, 2021). Although the government of Puerto Rico states that only 64 people initially died as a consequence of Hurricane María, several researchers and journalists

reported the number of deceased to be in the thousands (Robles et al., 2017; Kishore et al., 2018; Santos-Burgoa et al., 2018; Weissenstein et al., 2018).[11] The devastating death toll and experience have a high probability of happening again, reinforcing the urgent need to improve disaster management strategies.

Material and Methods

We conducted a content analysis of Hurricane María related Tweets before, during, and six weeks after landfall on Puerto Rico. A total of 2315 Hurricane María related Tweets were analyzed to identify who used Twitter during this time and how it was used during and after the hurricane in response to the crisis.

Data Collection

Tweets issued between September 16 and November 7, 2017, were collected. Live tweet counts were collected (a random 1% sample) using Twitter's open streaming application program interface (API), which has been shown to be representative of Twitter's greater information database and, therefore, useful for research purposes (Le et al., 2019). Tweets with geocode information were retrieved. The streaming API can take three parameters: keywords (i.e., words, phrases, or hashtags), geographical boundary boxes, and user ID. In using Twitter data for this study, we complied with Twitter's terms, conditions, and privacy policies (Twitter, 2020).

Using a text analytics platform, Texera (Wang et al., 2017), a keyword search query was performed to retrieve Hurricane María related tweets from an original sample of 5 million tweets

[11] Four elements contributed to discrepancies between officially reported and actual deaths: delay or interruption of medical care in the months after the hurricane, government employees were not uniform in how they counted deaths, local governments withheld death certificates and government inaction in the aftermath (Robles et al., 2017; *Centro de Periodismo Investigativo, INC vs Wanda Llovet Díaz*, 2018; Kishore *et al.*, 2018; Santos-Burgoa *et al.*, 2018; Weissenstein et al., 2018).

during these eight weeks. The initial search terms Risk, Maria, Puerto Rico, Gobierno and FEMA. The query included searching for the same terms but with a hashtag since using a hashtag symbol is common in social media dialogue. A sample of several hundred tweets were reviewed manually to identify additional, relevant keywords to narrow the scope of messages containing information about Hurricane María and yield clean data. After refining search terms to reduce non-relevant tweets, the final search strings included: 1) FEMA and Puerto Rico, 2) Hurricane and Maria, 3) *Gobierno* and Puerto Rico, and 4) Puerto Rico and Maria; the search retrieved 2315 tweets. Duplicate and nonsense tweets, which comprised 14.5% (n=121), were marked as trash and removed from the analysis, making the final sample 2194.[12]

Data Analysis

The final sample of 2,194 tweets were manually content analyzed. Content analysis is a widely used approach to analyze bodies of text (Krippendorff, 2018) from numerous forms of human communication, including social media (Tracy, 2012; Berg and Lune, 2013). Codes were adopted directly from the functional framework for disaster social media (Houston *et al.*, 2015) and include their hypothesized functions that social media can play as well as the actors who communicate on social media (Table 1).

Table 1. Code Names & Definitions

Code Label	Definition from Houston et al. (2015)
SOCIAL MEDIA DISASTER FUNCTIONS	
Provide & receive disaster information	Provide and receive disaster preparedness information

[12] The rate of non-relevant Tweets reflects a relatively low percentage compared to similar studies (Dann, 2010).

Provide & receive disaster warnings	Provide and receive disaster warnings
Signal & detect disasters	Signal and detect disasters
Send & receive help	Send and receive requests for help or assistance
Inform one's condition or location	Inform others about one's own condition and location and learn about a disaster-affected individual's condition and location
Document what is happening	Document and learn what is happening in the disaster
Deliver & consume news	Deliver and consume news coverage of the disaster
Provide & receive disaster response info	Provide and receive disaster response information; identify and list ways to assist in the disaster response
Raise awareness of disaster event	Raise and develop awareness of an event; donate and receive donations; identify and list ways to help or volunteer
Disaster mental health support	Provide and receive disaster mental/behavioral health support
Express emotion	Express emotions, concerns, and well-wishes; memorialize victims
Disaster response & recovery	Provide and receive information about (and discuss) disaster response, recovery, and rebuilding; tell and hear stories about the disaster
Discuss socio-political & scientific causes	Discuss socio-political and scientific causes and implications of and responsibility for events
Reconnect community members	(Re)connect community members

Traditional crisis communication	Implement traditional crisis communication activities
SOCIAL MEDIA USERS	
Individuals	Stand-alone users
Organizations	Non-governmental organizations and private businesses
Government	Government officials, agencies, and counties
News Media	News media outlets
Community	Shared interest groups (e.g., schools, colleges, and online groups)

We assigned each tweet a function code best reflecting its content. After a first-round of classifying tweets, we went through a second round to verify that we were applying the most appropriate "disaster function" code to each tweet. In the second round of coding, we paid special attention to the use of supplemental functional message properties, e.g., emojis and hyperlinks, to observe if they changed the message's meaning. We similarly categorized each tweet by associated user type.

After classifying tweets by function, a series of descriptive statistics were computed to compare and contrast social media function by (a) user type, e.g., individual, community, government, news media, organizations, (b) disaster phase (pre-event, during, and post), and (c) geographic location, i.e., by state (including Puerto Rico).

Results

Of the 15 disaster social media functions, we empirically identified 14 that were used before, during, and after Hurricane María made landfall in Puerto Rico.

Table 2. Twitter Disaster Communication Functions, Frequency, and Examples

Function	Count	Example
Deliver & consume news	686	*Hurricane #Maria is now Cat5 strength w/ 160mph sustained winds. It's the 2nd Cat5 #Irma storm this… https://t.co/EnqKuaSua4*
Discuss socio-political & scientific causes	550	*Puerto Rico Accused of Fudging Hurricane Maria Death Toll|News|teleSUR https://t.co/zvzIzZKZeX*
Express emotion	341	*Prayers out to those people in the Caribbean Islands as Hurricane Maria heads towards them. Really is insane what's going on there*
Raise awareness of the event	240	*@hardball Seriously, @realDonaldTrump @FEMA, the ppl of Puerto Rico need clean water. Send it to them!*
Send & receive help	154	*@Patrickglobe there are many groups in FB for finding people and Hurricane Maria PR updates. this one of many, coul… https://t.co/zJKw1Hs771*
Provide & receive disaster response information	77	*Taking matters into my own hands & starting a Hurricane Maria relief effort for Puerto Rico! Any donation helps & RT https://t.co/q0RzXa3Phe*
Inform about one's condition or location	67	*Drone Video Emerges From Puerto Rico Shows Flooded Streets In San Juan After Hurricane Maria https://t.co/tGRGwQY9YC*
Traditional crisis communication	*43*	*Thank you for all the great work you've been doing in Puerto Rico over the past week, @fema @USCG @USNavy @USNationalGuard @USDOT, etc.*
Signal & detect disasters	31	*Three weeks after Hurricane Maria, hospitals in Puerto Rico are *still* running on a generator. https://t.co/Ycp3BTUESt*
Document what is happening	23	*Listen to the wind at before the eye of Hurricane Maria reaching San Juan, Puerto Rico, at 7:50 am… https://t.co/FXSne8gz7D*
Provide & receive disaster information	7	*Caribbean islands prepare for Hurricane Maria - BBC News https://t.co/NhzH4lcAec*
Provide & receive disaster warnings	7	*I saw this on the BBC and thought you should see it: Puerto Rico dam bursts in wake of Hurricane Maria - https://t.co/bys9Nwr4K7*

Disaster mental health support	7	*#Hurricane & tropical storm distress warning signs, emotional support resources via @distressline https://t.co/l8n05NGpyr #Maria*
Disaster response, rebuild, recovery	3	*How to help Puerto Rico: 10 things you can do for Hurricane Maria victims right now https://t.co/YHDuELvaAm*

Table 2 reflects that the predominant function (31% of tweets) was *Deliver and consume news coverage.* Examples from this function category included users tweeting and retweeting links or excerpts from news articles about Hurricane María. Common messages from this function described the hurricane's trajectory, wind speed, consequences, and death toll.

The second most prevalent function was *Discuss socio-political and scientific causes*. Within this function, most tweets focused on discussing socio-political implications: [e.g., *@WhitefishEnergy and FEMA are playing games with lives in Puerto Rico. This is an absolute disgrace and disaster. #MAGA*]. Users emphasized Puerto Rico's dire situation in the aftermath of Hurricane María and its connection to the political situation with the U.S. Other messages in this function focused on Puerto Rico's socio-political condition as an element mediating the U.S executive and federal branches' response.

The third most prevalent function was *Express emotions.* Most of the messages in this function were aimed at sharing concerns about the situation on the island. An example of this type of tweet was: [*To all those impacted by Hurricane Maria: our thoughts & prayers are with you. To those affected in Boston: your City is here for you*.] Tweets such as "pray for Puerto Rico" or "my prayers are with Puerto Rico" were expressed often. Other tweets in this category include people expressing similar sentiments about the earthquake that occurred in Mexico

around that time: [*Mexico and Puerto Rico, two sore thumbs for the USA. But they will NOT be ignored. Mother Nature says. #hurricane #earthquake #maria #help*].

The fourth most prevalent function was *Raising awareness*. These tweets raised awareness in several ways; some pointed out how Puerto Ricans are U.S citizens, while others called attention to the dire conditions, e.g., that people had no access to water or food for weeks. Many messages under the function *Raising awareness* highlighted the post-recovery needs of communities impacted by the disaster by encouraging people to donate, including where to donate. An example of this type of tweet was: [*There is a crisis in Puerto Rico after #Maria. I encourage you to do what you can locally: https://t.co/8LAoQgyW34*].

The fifth most prevalent function was to *Send and receive help.* This function called users attention to the disaster, with many using #Maria to amplify their message and bring attention to the issue. Tweets also provided assistance information for impacted groups or focused on transmitting information on where to get resources.

Social Media User Types

Different types of users were active on Twitter in response to Hurricane María, with all five user types proposed by Houston et al. (2015) present in our dataset (Figure 1). The vast majority of tweets (82%) came from individuals. This category included scientists, faculty, teachers, police officers, lawyers, celebrities among others. News media outlets, which included journalists, TV anchors, and radio stations, accounted for 12% of tweets. The organization category (4% of tweets) included non-governmental organizations (e.g., Red Cross, Salvation Army) and private businesses, including apps such as Hurricane Pro and businesses in Puerto Rico like Dominguez Auto. Government users (1.4% of tweets) included U.S. government

officials and institutions (e.g., FEMA, U.S Army). Finally, community users (0.7% of tweets) included college campuses, high schools, and online groups, such as Facebook groups.

Figure 1. Twitter Use by Different Actors

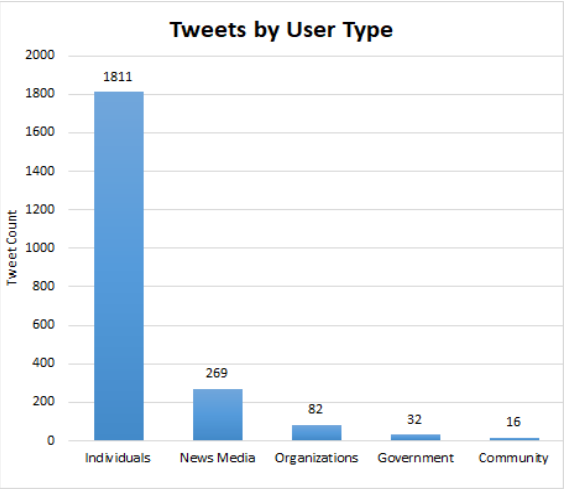


Table 3 provides the most frequently tweeted categories by user type. Individuals, News Media, and Organizations had *Deliver and consume news* as their top tweeted function. The top function for Governments was *Discuss socio-political and scientific implications,* and for Community was *Raise awareness* tied with *Deliver and consume news*. For four of the five user types, Twitter functioned to deliver and consume news as carrying the most important function. For the second most-frequent Twitter function, users were focused on either raising awareness about the disaster event or discussing political and scientific causes of the event. Individuals, Organizations, and Communities had *Express emotions* as their third top function, while governments were delivering and consuming news. While expressing emotions is good, the government made little use of this function.

Table 3. Top Categories by User Type

Ranking	Individual	News Media	Organization	Government	Community
1	Deliver & consume news (30%)	Deliver & consume news (62%)	Deliver & consume news (45%)	Discuss socio-political & scientific causes (27%); Raise awareness (27%) (Tied for 1st)	Deliver & consume news (33%); Raise awareness (33%) (Tied for 1st)
2	Discuss socio-political & scientific causes (25%)	Discuss socio-political & scientific causes (14%)	Raise awareness (23%)		
3	Express emotions (17%)	Raise awareness (10%)	Express emotions (18%)	Deliver & consume news (19%)	Discuss socio-political & scientific causes (11%); Inform one's condition or location (11%); Express emotions (11%)
4	Raise awareness (10%)	Inform one's condition or location (4%)	Provide & receive disaster response info (5%)	Send & receive help (8%); Express emotions (8%); Provide & receive disaster response info (8%)	

Temporal trends

We drafted a timeline to observe how Twitter use evolved (Figure 4). Tweets increased as the Hurricane approached Puerto Rico. The highest tweet count occurred the day Hurricane María became a Category 5 and declined rapidly when the hurricane made landfall. Other smaller peaks occurred after the event; these included when (1) Guajataca Dam broke, (2) former President Trump waived the Jones Act, (3) Statistics on Puerto Rico's drinking water access and electricity were deleted from the FEMA website, (4) EPA found that people were

drinking water from a Superfund site, and (5) Trump suggested that we would pull aid from Puerto Rico.

Figure 2. Timeline of Hurricane Maria Tweets

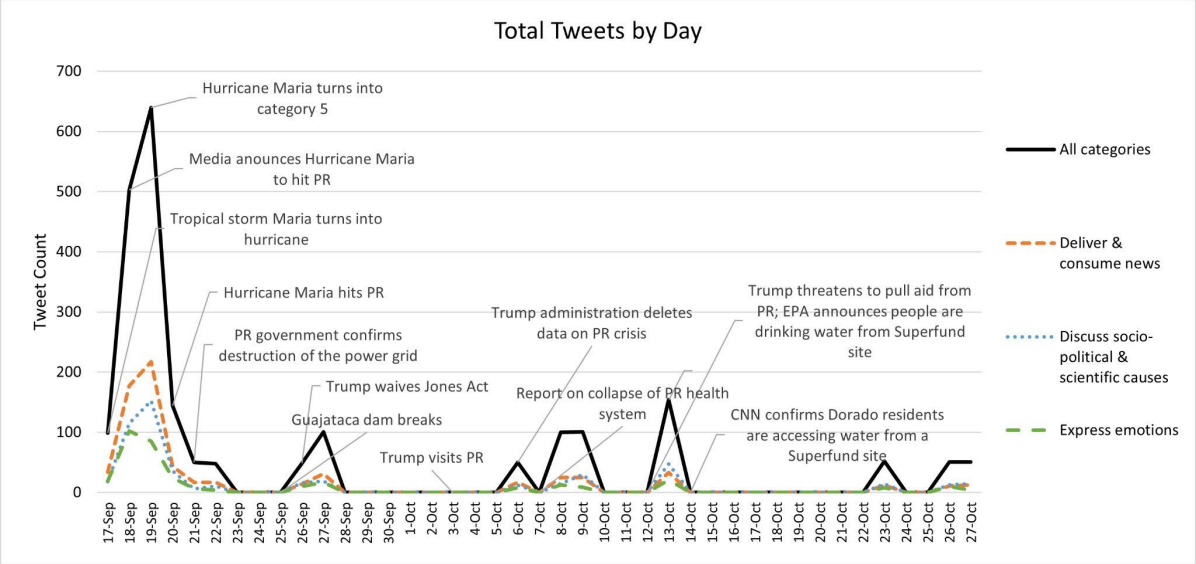
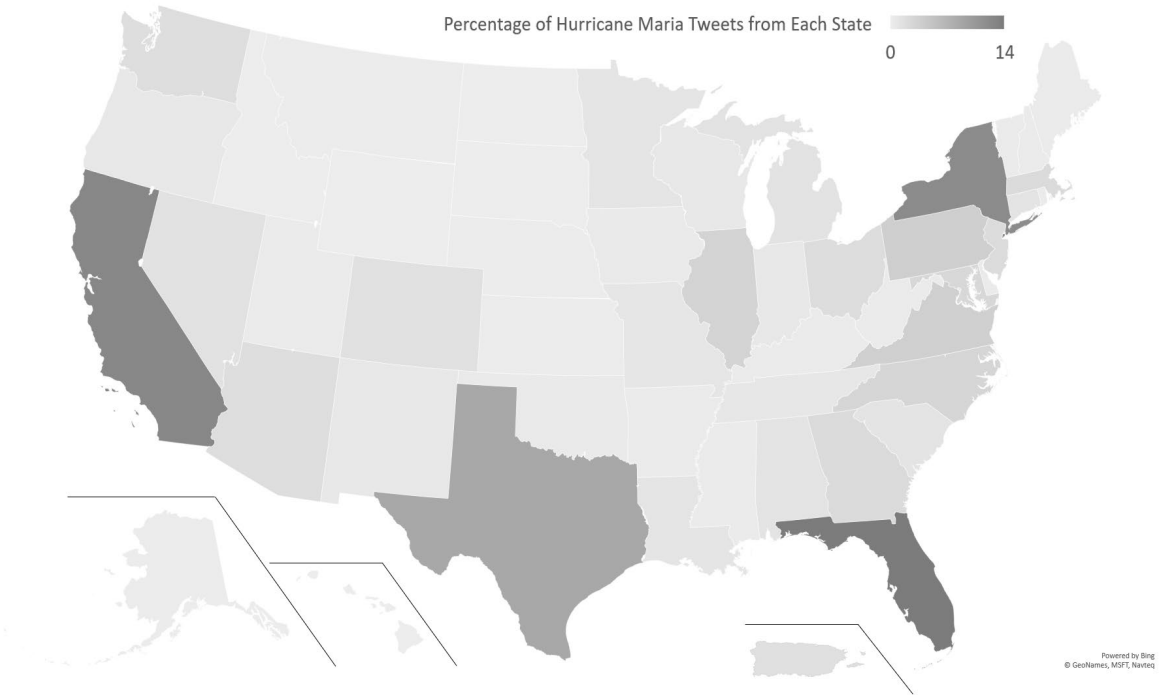


Figure 2 includes the timelines for the three most tweeted categories. The categories *Deliver and consume news coverage* and *Discuss socio-political and scientific causes* peaked the day Hurricane María turned into Category 5, mirroring overall trends. The function *Express emotions*' highest day was the day it was announced that Hurricane María would hit Puerto Rico.

Geographic trends

We assessed the geographic distribution of Tweets across the U.S. (Figure 3). We observed tweets from all 50 states, Puerto Rico, and the District of Columbia, but these tweets were highly concentrated in a few states. States with the most messages were Florida (n=315), California (n=282), New York (n=270), and Texas (n=193). No other state had more than 85 tweets, and 41 states had fewer than 50 tweets. Only 64 tweets were geotagged from Puerto Rico; the low message count in Puerto Rico may have been cause doe to the island's power grid destruction; still, they had a higher count than many other states.

Figure 3. Percentage of Hurricane Maria Tweets from Each State (including Puerto Rico)



The most tweeted functions varied greatly in the states with high tweet counts. See Table 4 for the distribution of top functions by regions with most messages, including Puerto Rico. The function *Deliver and consume news* was the leading function in Florida, New York, and Texas, while in California, the top function was *Discuss socio-political and scientific causes.* In Puerto Rico, the top category was *Inform one's condition and location*.

Table 4. Top Tweet Functions in States with Most Tweets and Puerto Rico

Ranking	Florida	California	New York	Texas	Puerto Rico
1	Deliver & consume news (108)	Discuss socio-political & scientific causes (92)	Deliver & consume news (66)	Deliver & consume news (61)	Inform one's condition & location (17)

2	Express emotions (68)	Deliver & consume news (91)	Discuss socio-political & scientific causes (63)	Discuss socio-political & scientific causes (48)	Express emotions (10)
3	Discuss socio-political & scientific causes (59)	Raise awareness (32)	Raise awareness (52)	Express emotions (30)	Send & receive help (9) *Tied for 3rd
4	Raise awareness (27)	Express emotions (30)	Express emotions (49)	Raise Awareness (19)	Deliver & consume news (9) *Tied for 3rd
5	Send & receive help (25)	Send & receive help (15)	Send & receive help (14)	Send & receive help (15)	Document disaster (7)

Discussion

This paper presents an empirical application of the Houston et al. (2015) functional framework for disaster social media use. Our Hurricane Maria tweet analysis validates or offers the first step in a process to validate the functional framework with real-time social media user disaster response. We highlight how the framework behaved under a real-world, real-time scenario. We also evaluate the framework and suggest areas to extend it.

How social media was used during Hurricane María

This article reveals how Twitter was used during Hurricane María predominantly by individuals and media agencies, government, and organizations. Social media plays a role increasingly in disaster and emergency response situations. These occur with increasing frequency across the globe, especially when they are climate-related, impacting communities'

wellbeing (Chu and Yang, 2020; Sutton et al., 2020). Understanding how social media is used in real-time, by whom, and how it can be strategically applied plays an increasingly critical role in the need to provide rapid and reliable information to communicate safety issues. Our results highlight that social media was used especially during but also after Hurricane Maria primarily to understand what was happening on the ground in Puerto Rico as our top function was *Deliver & consume news.* Not only did this function of alerting others about the weather conditions have the highest frequency, but it was the top function for four of the five user types. Users shared news posts containing vital information as well as copied and pasted news media quotes in separate messages.

Our second most prevalent function, *Discuss socio-political & scientific causes,* revealed that users were very interested in understanding the causes that turned the hurricane into a disaster. This function was the government's top social media function and the second most frequent for individuals and news media. This function also highlighted political tensions between the U.S and Puerto Rico that have existed since the island became a territory of the former in 1898. The following messages highlighted this tension:[*FEMA deputy director just called Puerto Rico "a country." This is a problem. They don't understand that Puerto Rico… https://t.co/ft4oANXnKx*], [*Trump accused San Juan's mayor of "poor leadership" after she criticized federal efforts to help P.R. after Hurricane Maria SOB PRESIDENT*].

People also used the platform to voice what they were feeling, experiencing, and immortalize victims, as our third most prevalent function was to e*xpress emotions and show appreciation*. Most messages in the *Express emotion* function were positive [*e.g., Thank You for Your Support of the Victims of Hurricane Maria And the American Citizens of Puerto Rico! https://t.co/ymozCVWuVe*] and came as words of solidarity. This social media function has also

been observed in flooding events like in South Carolina (Brandt et al., 2019). Hate messages were also expressed, such as those that made fun of the situation on the island or depicted Puerto Ricans in a derogatory way. Some examples of negative messages were: [e.g., *@shannonfarren Puerto Rico hammered by Hurricane Maria, but they are Mexicanish, so we should all have a good laugh about it. Right?* ��], [*Maria is just doing what Harvey failed to do, wipe the filth ridden, smelly island of Puerto Rico off the map.,GO MARIA, GO!!!! Stay 3 days*].

In examining temporal trends, the majority of the tweets occurred prior to landfall. The day with the highest frequency was when the Hurricane became Category 5 and made landfall in Puerto Rico. Fewer tweets were issued after landfall, with the event more or less disappearing over the following weeks except for a few minor peaks. We also observed no Twitter discussion during a few important events, for instance, the signing of the Whitefish contract on October 17 (a $300 million contract to repair the electrical grid) or an outbreak of leptospirosis that started in September 2016 and continued to grow past October. Most surprisingly, we expected President Trump's visit to the island would have triggered a peak. Trump's visit to the island caused great turmoil. He tossed paper towels like it was a basketball game to a crowd full of people that lost everything and also praised local government efforts to address the crisis while local leaders and entities revealed the high death toll as a cause of government inaction (Weissenstein et al., 2018).

At the same time, a few more minor events triggered more widespread responses. For example, on September 22, 2017, a day after reports confirmed the destruction of the island power grid, former President Trump tweeted about NFL players kneeling during the national anthem. That sparked a wave of messages critiquing the president by focusing more on National Football League (NFL) players than on what was happening in Puerto Rico in the aftermath of

Hurricane María. The following tweets are examples of this event: [*Since Maria made landfall in Puerto Rico, @realDonaldTrump has mentioned Luther Strange 6 times, NFL/kneeling 8 times-P.R. twice. F'n sad!*], [P*uerto Rico & the USVI are destitute from Irma & Maria, and Trump is tweeting at NFL/NBA players. Priorities. @POTUS @realDonaldTrump*]. Another event that triggered a wave of messages occurred a week after the hurricane when FEMA deleted Puerto Rico's disaster statistics from its website. The following messages are examples of the message response: [*FEMA restores deleted Puerto Rico stats after uproar https://t.co/JWPKUUG0sr #fema #PuertoRico #Resistance*], [FEMA deleted inconvenient facts from its Puerto Rico recovery site, all to bolster Trump's fictions. Heckuva job. https://t.co/ghCGvPbb3E]. Social media functions may be beneficial post-disaster to not only describe devastation occurring but to highlight the resources needed, identify actions to reduce pending and imminent health threats, and elicit help, awareness, and resources (Brandt *et al.*, 2019; Chu and Yang, 2020; Sutton, Rivera, *et al.*, 2020).

Regarding Twitter user type during Hurricane María, our data reveal that most messages came from individuals. Twitter use predominantly by citizens during flooding and hurricanes has been increasingly observed, such as during historic flooding in South Carolina in 2015, Colorado floods in 2013, Louisiana flooding in 2016, and Hurricane Harvey flooding in 2017, to name a few (Brandt *et al.*, 2019; Chu and Yang, 2020). When an event like Hurricane Maria occurs, individuals and news media can trigger the coverage of an event (Olteanu et al., 2015). This brings to light individuals' capacity to create and begin their own narrative about an event. We also saw many messages claiming that the news media were not covering the event since literature points out that mainstream media is 20% more favorable in terms of covering disasters (Olteanu *et al.*, 2015).

Surprisingly, relatively little use came from organizations. Low participation of organizations pushes against literature highlighting that first responders and relief organizations are increasing their presence on the platform (Landwehr and Carley, 2014; Murthy and Gross, 2017). Their limited participation may respond to the fact that organizational response to disasters can be slow at times, as they require logistics and security-based practices that require significant trust (Tapia and Moore, 2014). Our findings suggest that organizations are still integrating social media into their activities. However, we need to approach these findings with caution, as it may be that a small percentage of organizations were captured in our sample.

The four states with the highest percentage of Tweets were Florida (14%), California (13%), New York (12%), and Texas (9%). Except for Florida, these states have the highest social media (Taneo Digital), 2020) connections[13] and the highest population in the U.S., so it makes sense that they have the highest percentage of Tweets about Hurricane María. Additionally, these states have very high concentrations of Puerto Ricans outside the island (Collazo et al., 2008). We also found that the topics people tweeted about when they were located at the disaster site were quite distinct from those located on the mainland. Users observing the event from afar were interested in consuming news, expressing emotions, and discussing the responsibility behind the event. However, Twitter users in Puerto Rico were using social media to *Inform one's condition and location*, *express emotions*, *send & receive help*, and *Document disaster.*

Validating the Functional Framework

All fifteen functions from the Houston et al. framework were present in our empirical data except for *Reconnect community members.* The absence of this function may indicate that reconnecting community members occurred outside the timeframe in which we collected data.

[13] Social media connections refers to the total number of connections of users to Facebook, Instagram, Twitter, LinkedIn, Snapchat, and TikTok.

Transportation in and out of the island was minimal and difficult for the first months after the hurricane. Thus, by the time people could return and reconnect with family members, this may have occurred after the months we collected data.

One challenge when utilizing the framework is that some categories are extensive, which can falsely suggest that all the messages in one multi-dimensional function are equally distributed. For example, most messages on the function *Discuss socio-political & scientific causes* focused on socio-political causes, not scientific ones. Splitting this function into two would capture this nuance. Likewise, the function *Raise awareness* included three types of messages: Raise and develop awareness of an event; donate and receive donations; and identify ways to help or volunteer. When we look closely at this data, most messages for this function were about donating and receiving donations. We also suggest a split for this function.

This research extends the functional framework by noting which users engage with which functions since the original framework does not cover this. Within the top user categories, a few findings were striking. From all the actors, the government's top function was *Discuss socio-political & scientific cause* tied with *Raise awareness*. This was surprising since most of the messages from the category *discussing socio-political and scientific causes* blamed different government branches as being responsible for the lack of relief and efforts to aid in the disaster. Community users' top concern was *News coverage* tied with *Raise Awareness*. Messages raising awareness informed communities where to donate and denounced the inadequate government response. An example tweet exemplifies the "raise awareness" function:: [*Thank God for the media because listening to DHS FEMA & Trump u would believe Puerto Rico was a good news story.… https://t.co/49sUKVct62*]. Social media provides a space that users can use in real-time to signal their location with respect to their condition, including a warning from possible perils.

Soliciting resources and donations during post-hurricane phases is certainly a critical time to communicate the need to minimize loss of life and adverse health outcomes.

While there are emerging social media platforms (e.g., Discourse, TikTok), Twitter and Facebook still dominate social media approaches to analyze disasters. Facebook has even created a function that can mark people's safety when a person's location matches that of a disaster. Because disasters are non-routine, people tend to "improvise," which brings all kinds of social media usages (Sutton et al., 2008). This article's results complement other research using Twitter and Facebook. Other articles that use social media to analyze disaster conditions highlight Facebook and Twitter as tools that empower the public with a new role in actively influencing disaster and risk outcomes (Liu & Xu, 2018; Feldman et al., 2016). Research keeps signaling the importance of the public's role in providing useful local updates and advice for disaster management officials by posting or commenting on social media (Liu & Xu, 2018). Facebook behavior under disaster conditions has been similar to those on Twitter. Members posted information and questions, and residents asked for and received help and advice (Bird et al., 2019). Moreover, an article comparing Twitter to Facebook in the aftermath of an earthquake found that the dominant use of social media was to provide 'news'(Muralidharan et al., 2011), which is aligned with my findings. In that same research, the authors emphasize that Facebook usage decreased much earlier in the disaster timeline than Twitter, suggesting Twitter's strong potential as a communication tool under disaster conditions.

Finally, the original framework proposes that each function occurs during specific disaster phases: pre-event, event, and/or post-event. In our data, some categories expanded beyond their hypothesized phases to include another. For example, the function *Discuss socio-political & scientific causes* was active and had minor peaks through all three phases of the

Hurricane event. This differentiates significantly from the original framework, which restricted this function to the post-event phase. Another function present in a different stage was the category *Providing and receiving disaster warnings*. In the framework, this function is hypothesized to occur pre-event. However, we observed empirically that this tweet function also occurred post-event. For instance, two days after the hurricane, one of the island's dams collapsed, creating a ripple effect of people sending messages through social media about the potential of disasters for such an event: [*Hurricane Maria Live Updates: Structural Damage at Guajataca Dam Prompts Evacuations in Puerto Rico https://t.co/I4ensYSbAE*]. These examples bring to light the idea that categories can be identified or distinguished as evolving through different phases depending on the disaster; their boundaries are not static but rather evolving.

Practical Implications

This paper exemplifies the diverse uses of Twitter as a social media tool in disaster conditions. Our data revealed that the primary function served to seek and consume news—this reflected user needs to understand what was happening in real-time and alert others of the weather conditions. Furthermore, accessing critical data during and after a disaster can provide the difference between life and death. Recognizing the increasing use of social media for disaster response and aid can increase communities' disaster resilience. This was observed during Hurricane Harvey in Houston, Texas, in 2017 (Chu & Yang, 2020) and may help, especially when the communities hardest hit have limited communication and are remote, as in the case of Puerto Rico.

Another insight drawn from the function *Express emotion,* a top function, was that this function forces us to pay attention to the emotional toll of a disaster, both close and far from the event. The event also revealed the individuals' capacity to call attention and provide a real-time

narrative of what was happening on the ground, different from what government official media outlets were reporting. While we did not include sentiment analysis, we observed the daily uncertainty experienced and expressed by people on the island post-event. At the same time, we saw great expressions of solidarity and aid—suggesting that even when the island was in a complete blackout, the first to respond to help of the people were other people on the ground nearby. These individuals become the local experts. We also saw how social media was used to inform where to get resources for health conditions, e,.g: [#Hurricane & tropical storm distress warning signs, emotional support resources via @distressline https://t.co/l8n05NGpyr #Maria]. Highlighting resource distribution and volunteer opportunities is another critical disaster role of social media in response and recovery (Brandt et al., 2019).

Limitations and future research

Although this study provides theoretical and practical implications for future research, it is necessary to note some limitations. First, the study was based on a random ~1% sample of keyword-queried Hurricane María tweets retrieved during the fall of 2017 when the Hurricane occurred. A study of different Twitter data-sampling strategies showed that a random sample detected a similar number of themes as a topic sample suggesting that it was helpful in qualitatively assessing frequencies (Le et al., 2019).

We hoped to observe the Twitter usage originating from Puerto Rico, but since Hurricane María destroyed the power grid and affected communication, the total number of Twitter messages sent from Puerto Rico was low. Furthermore, Puerto Rico is at the edge of the geographic region from which the application programming interface (API) retrieves tweets, and some tweets may not be captured. However, even the small number of messages from Puerto

Rico reveals one of the advantages of Twitter: it does not require a strong signal or connection; sending messages under disaster conditions is more accessible.

While the objective of our paper was not to correlate external events with specific trends and tweets using statistical models, we cannot overlook how external events may play a role in influencing trends and shaping specific topics. Additionally, "social media may act as a conductor orienting people to official sources of information and amplifying these messages to a broader audience" (Taylor et al., 2012, p. 24). Understanding better why certain events trigger social media responses while others do not can further our knowledge of why individuals turn to social media during disasters.

Future research should explore how different groups (e.g., individuals from different socioeconomic levels) use social media during disasters. This could reveal if there are populations that rely more on social media and why. By knowing this, governments and organizations can take a more targeted approach when investing in tools to increase societal resilience. Also, future research can draw a comparison between Twitter and other social media platforms to observe how they can diverge or be used similarly under disaster conditions.

Conclusion

As we move forward and address future disasters, strengthening our understanding of how social media is used during disasters can help promote more effective planning and recovery, including how individuals understand and cope with disasters. This paper suggests several extensions to Houston et al.'s (2015) functional framework for disaster social media. First, individual functions extended across multiple stages of the event (pre, during, and post), suggesting the need for a more flexible understanding of the boundaries between these stages. This is critical for disaster communication policies, as it reveals that social media functions can

occur through the event, not only within specific stages. Second, most messages occurred before landfall, not during the event itself or the recovery, surprisingly suggesting that social media could be deployed more actively to help with recovery. Third, individuals overwhelmed other user types, being the main user in engaging with Hurricane María-related content; this suggests an opportunity for a more nuanced understanding of the roles social media plays for different user types. Behavior across user types was similar in terms of the main function (*Deliver and consume media*), except for governments whose primary function was *Discuss socio-political and scientific implications* tied with *Raising awarenes*s. Fourth, adding a geographic dimension can highlight how people experience the event differently depending on the region.

Understanding how people with no direct connection to a disaster (geographically and perhaps socially) perceive the event can help inform how broader support networks form to encourage or discourage particular types of volunteer and/or government responses. By continuing to refine the disaster functional framework through its application to new hazard and disaster events, researchers can help promote more resilient and equitable disaster management.

CHAPTER 3 : MOBILIZING SMALL WATER SYSTEMS: THE CASE OF PUERTO RICO'S INDEPENDENT AQUEDUCTS

Introduction

Access to clean drinking water is critical for the survival of all human beings. This makes its governance essential to ensure equal access, consumption, and conservation of the resources. Moreover, as the world population increases and extreme weather events become more frequent, adapting and managing these pressing challenges becomes crucial for governments.

Under our current climate change context, extreme weather events such as heatwaves, heavy downpours, and hurricanes are increasing (IPCC, 2018; Ornes, 2018; Peterson et al., 2012; Reidmiller, 2019). Their impact affects human livelihood, not only the economic impact of destroying infrastructure but also the high impact on the loss of human life. Therefore, looking for ways to cope with them is not only relevant but vital to human survival.

Extreme weather events or disasters can stress the water supply and the system transporting water to its users. For example, water treatment plants can stop working due to high turbidity levels, blockages due to debris, and lack of electrical power to operate. These events affect the continuous supply of clean drinking water to residents. Therefore, it is critical to create the conditions that guarantee access to drinking water even under disaster conditions. It is important to remember that shortages or lack of drinking water do not affect everyone equally. Those with fewer resources have to dedicate a disproportionately more significant portion of their salary to buying bottled water or accessing water that is not necessarily clean (Belluz, 2018; Marinova-Petkova et al., 2019).

Resource mobilization is one way to promote water resilience during disasters and extreme weather events. Generally speaking, resource mobilization theory argues that the success of a collective or social movement depends on its resources (time, staff, labor, skills,

among others) and its ability to use them (McCarthy & Zald, 1977; Edwards & McCarthy, 2004). Grassroots collectives and organizations are vital in this process, especially under environmental hazards. The way different stakeholders access and put resources in motion has an impact on the way they manage their water resources and deal with disasters. Drawing from resource mobilization theory, this paper seeks to identify the conditions that give rise to resource mobilization in the face of cascading disasters, and whether resource mobilization affects disaster resilience (measured as time to recovery).

This paper focuses on the case of independent community aqueducts in Puerto Rico[14], which are small water systems that are locally referred to as non-PRASA systems because they fall outside the Puerto Rico Aqueduct and Sewer Agency (PRASA) water grid. Non-PRASA communities or independent community aqueducts are located typically in rural areas and often provide the only means for residents to access clean water. In the aftermath of disasters like Hurricanes Irma and María and the series of earthquakes in 2020, they remained the only option for some communities to access drinking water. These communities have created their water supply infrastructure, including primary and, in some cases, secondary treatment processes. Although these systems can serve up to 100,000[15] active users, they are sometimes deemed primitive, ineffective, and unsafe by local officials (Arce-Nazario, 2018), including that many of them have the majority of their residents living below the poverty line index (CENSUS, 2020). Some of these systems have a limited technical capacity and financial resources, little to no institutional support, and high operating cost. These challenges have a detrimental impact on

[14] While Puerto Rico is legally considered a commonwealth of the U.S, geographically is located in the global south, which has implications for the way we think about disaster and resource mobilization in the global south

[15] This number is an approximation; it fluctuates pre- and post-Hurricane María and is affected by migration.

their water systems, as many are non-compliant with water clean act regulations, both local and federally.

This chapter draws on a survey of community aqueducts to observe how they have mobilized resources to recover from disasters and how that mobilization can yield positive water management effects. First, this article presents a short discussion on resource mobilization theory, including its implication for social networks, water governance, and recovery—research hypotheses are included in these sections. Afterward, I explain how I created the survey instrument and resource mobilization index, identified the targeted population, and briefly described the variables used for the statistical models. Next, I present findings from the two OLS models: the first model identifies the critical aspect of resource mobilization in the context of disasters. The second model looks at the impact of resource mobilization on disaster resilience by looking at the disaster recovery time. Finally, after the findings, I discuss the implications of the models for community aqueduct resource mobilization and disaster recovery.

Literature Review and Hypotheses

The literature presented in this section discusses various factors that can affect communities' resilience and recovery time in the aftermath of a disaster. I draw upon social movement theory to explain how community aqueducts can mobilize to react to extreme conditions, in this case, disasters. Resource mobilization theory focuses on describing the contexts of social movements by first looking at the availability of resources and then observing how organizations obtain resources and mobilize them for said movements (McCarthy & Zald, 1977; Edwards & McCarthy, 2004). Looking at resource mobilization theory is critical to observe strategies that allow the movement of resources and how they can be maintained over time. It looks at how aqueducts can build social capacity and allocate resources to address

disasters and water management problems. Within resource mobilization, this paper highlights the importance of social networks as a means for collective action, mobilization of resources, and recovery measures as they can lead to resilience outcomes (Aldrich 2012: Varda, 2017). This section presents literature that explains how social networks support resource mobilization, followed by a discussion on why resource mobilization is expected to impact water governance. I conclude with a discussion on resource mobilization's impact on disaster recovery.

Social Networks and Resource Mobilization

Resource mobilization theory claims that social movements tend to be organized among networks of individuals and groups. Resource mobilization in practice requires some degree of organization and inter-organizational cooperation that networks can provide. As a result, collective action and the creation of voluntary and activist groups are essential components of social movements. They offer the space needed for groups to conduct their everyday work of coordinating and reproducing material resources that lead to collective action (Hunt &Benford , 2004). Establishing a group requires that individuals and constituents be brought into a collaborative environment where others can associate, strengthening the activists' ability to gather more resources, generate a coordinated campaign, and carry out social movement actions (Cress & Snow, 2000). Resource mobilization argues that social movements tend to be highly organized among networks of individuals and groups.

Social movements can be defined as networks of informal interactions between a plurality of individuals, groups, and organizations engaged in political or cultural conflicts based on shared collective identities (Diani, 1992). The consideration that community aqueducts can be considered a social movement brings forward the following. First, community aqueducts are a collective that join together to form networks of small water systems in different locations in

Puerto Rico. Community aqueduct can be collectively organized under regional (e.g., ASOCAGUAS, Cooperativa Acueductos de Patillas CAP COOP) or island wide efforts (e.g., Organización Sistemas Acueductos Non-PRASA de Puerto Rico Corp (OSAN) and Fundación Comunitaria de Puerto Rico). Secondly, some of these groups are politically engaging in collective actions that lead to policy implementation seeking to improve their water systems. These political activities include drafting policy, meeting public officials to discuss their concerns, and having informal conversations with street-level bureaucrats to access resources. These community aqueducts, especially the smaller ones, have a shared identity of communal water operators. Communal water operators are those that participate in the operation (including both the physical and organizational procedures) of the aqueducts but also provide social services to the community (e.g., tutoring services, helping the elderly, and recreational activities). Additionally, these political activities can occur at the community, state, and federal levels. Thirdly, they have been undergoing political campaigns advocating for common property resources to ensure water access and the continuous operation of their systems.

Successful collective action largely depends on movements' mobilizing structures to organize and present their claims (McAdam, 2017). In other words, social activities and groups cannot operate in a vacuum; they need a platform and structure to carry out their collective actions. These mobilizing structures can take the form of networks and institutions, which are vital for the emergence, sustenance, and impact of social movements and change (McAdam, 1999; Taylor & Rupp, 1987). These networks are essential for movement building, as they allow the exchange of resources through relationships (Juris et al., 2014; Cress et al., 1998). As such, I expect that networks would affect resource mobilization positively.

In addition to resource mobilization theory, social network scholarship highlights the importance of civil society groups and their inter-connectedness in the recovery process. For instance, research done after Hurricane Katrina has indicated a strong connection between civic engagement—such as involvement in associations and clubs—and recovery efforts and repopulation levels (Patel et al.,2010). Patel et al. (2010) also points out that the trust that individuals develop while collaborating within civil organizations plays a vital role in improving resilience strategies in the aftermath of disasters. Survivors with strong social networks can experience faster recovery as they have access to information, tools, and assistance through these prebuilt networks (Aldrich, 2012). However, while these networks may lead to positive outcomes, civil society remains critical to creating more significant opportunities for community actors on the ground to increase activism, specifically in providing the groundwork for future movements and organizations. Grassroots organizations can spring up quickly after a disaster in places with preexisting social activities (Luft, 2009). For example, after Hurricane Katrina hit New Orleans, grassroots organizations with political ties mobilized around 13,000 activists, including college students, to provide aid and services to people in need. These organizations could mobilize vital resources including people by building on previous national and local ties affiliated with political organizations.

I hypothesize that networks are vital for resource mobilization; they provide organization and coordination of collectives to access aid. They have the potential to shorten recovery time because they provide the space in which people can come together to plan and design actions leading to achieving a specific objective, such as getting critical resources in the aftermath of a disaster. Also, these networks provide the channels for communities to access those resources, for example, tapping into grassroots organizations to access funds to aid their recovery process.

H1: Increased participation and social networks from the community aqueduct will increase its resource mobilization score.

Resource Mobilization and Water Governance

Diverse forms of capital (e.g., social, financial, and human, among others) contribute to water communities' ability to mobilize resources. Water governance provides thorough groundings to understand the interaction between water communities and the systems that enable resource mobilization. Water governance can then be defined as the range of political, social, economic, and administrative systems established for developing and managing water resources and services at all scales (Rogers and Hall, 2003). Simultaneously, water governance is critical to water security and the long-term sustainability of Earth's freshwater systems (Baker and Morinville, 2013).

Decision-making procedures, including how decisions are implemented, can impact disaster resilience. Variation in these governance systems can yield different recovery outcomes, especially regarding how water is distributed, accessed, and paid for. Polycentric systems typically are those in which decisions are taken horizontal, while monocentric are those in which decisions are taken using a top-down approach. It is essential to highlight how their different objectives influence the networks they create, ultimately influencing how disaster resilience can play out. Communities are recognized for having the capacity to affect governance outcomes (Howard et al., 2017), a difference that has the potential to illustrate why or how some water governance systems are more resilient than others in the face of extreme events. Collaborative approaches, such as those that are polycentric, can build more just democratic systems and practices of governance, especially in the global south nations (Finewood & Holifield, 2015). In addition, water governance practices, especially those operating with a polycentric approach, allow stakeholders to connect in networks and build social capital and trust to potentially create

institutional change (Priscoli, 2004; Pahl-Wostl et al., 2007). Still, a polycentric system does not guarantee that decisions are taken collectively and horizontally, as they can reproduce top-bottom approaches. In the face of future disasters, it is critical to understand how different decision-making approaches can influence disaster resilience.

Community aqueducts would fall under what has been called 'rooted water collectives' or water communities. Rooted water collectives are instances of collective action, coordination, and shared governance arrangements that either engage in communal management of water systems (and may have two or more tier federations) or form a social movement that advocates for local common property resources management (Vos et al., 2020 p.1). Additionally, some rooted water collectives do both. The framework of rooted water collectives can be used to further our understanding of social mobilization concerning water (Vos et al., 2020). It also interrogates how collectives organize around water, built on participation, local knowledge, water culture, and collective decision-making while interacting with local government and regulators (Lankford and Hepworth, 2010; Komakech and Van der Zaag, 2013; Boelens et al., 2015). In addition, it interrogates how water collectives implement water governance principles that fit their necessities and how they use institutional tools to defend their collective resource management (Orlove and Caton, 2010; Johnston et al., 2012; Fuente-Carrasco et al., 2019). Rooted water collectives can be either multi-scalar organizations that engage in communal management of common property resources or multi-scalar organizations that form a social movement, in this case, community aqueducts.

Looking beyond formal institutions, like government-owned water utilities, is critical to understanding how water collectives act, especially in disaster/post-disaster research. Hence, alternative non-PRASA mobilization configurations can be identified, including political

activism. For example, they can mobilize as a single unit small water system at the local level to meet with mayors. Equally, they can mobilize regional or island-wide to draft policy or engage public officials to address their concerns.

The literature I reviewed contends that collective organizations can successfully protect catchment areas and river basins, managing rural water and irrigation systems (Vos et al., 2020). Furthermore, they are efficient in designing climate change adaptation and dealing with floods and droughts (Schulze & Schmeier, 2012). In addition to the latter, they have successfully managed water systems, especially in the global south (Ostrom, 1990; Boelens and Vos, 2014; Mutambara et al., 2016).

Resource Mobilization and Disaster Recovery

Stakeholder participation is critical to post-disaster recovery (Chandrasekhar, 2012; Nakagawa & Shaw, 2004). Mainly because participation helps create a shared understanding of local hazards, risks, and vulnerability, improves the efficacy of decisions made for recovery and mitigation and builds social capital and local resilience in the face of future disasters (Godschalk, 2003; Jones, 2003; Olshansky, 2006; Mathbor et al., 2007). Civil society organizations have emerged as critical players in the aftermath of a disaster, especially when federal funding, private insurance, and local government aid are not enough to cover losses (Lassa, 2018; Pahl-Wostl, 2009). A wave of actions is triggered when a disaster occurs due to an extreme event (e.g., hurricanes, earthquakes, wildfires); as a result, governments and civil society groups put plans and strategies to deal with those. Most notably, civil society sometimes fills the gap when governments lack the capability to provide potable water, food, medical services, and garbage disposal (Green et al., 2007). Consequently, non-profits have become the go-to entities in disaster response and recovery, primarily because of their perceived or actual capacity to identify

affected communities' needs and understand their sociocultural complexities (Acosta et al., 2011).

I hypothesize that high levels of resource mobilization from community aqueducts can result in lower recovery time. Community aqueducts and grassroots organizations in Puerto Rico have become vital in the recovery process by facilitating critical resources such as water and medicine (Roque et al., 2020). Furthermore, they have become the first line of defense when governments have limited capacity to aid their residents.

Non-profits play a critical role in the recovery after disasters. However, non-profits are often criticized for taking a technocratic approach and ignoring existing community power and trust structures (Chandrasekhar, 2012). Similarly, they can assume top-down rehabilitation plans that overlook the role of social resources in the recovery process after disasters (Aldrich, 2012). Nevertheless, when there is a lack of systematic assistance from the government and non-profits, neighborhoods and community groups are best positioned to carry out efficient initial emergency aid after a disaster (Aldrich, 2012, p. 46; Tsuji, 2001).

Not all non-profit and community groups are the same. They can vary by degree of professionalization, formalization, centralization, size, and strategy (McAdam, 1999). This variation is noteworthy; it can determine the success or demise of a collective organization. Traditionally, social movement literature has focused on well-established, traditional, and voluntary organizations that pursue ways to influence elites and the decision-making process (Cress & Snow, 2000). Most voluntary organizations are described by literature as groups that seek to participate in the provision of services and cultural activities—which may or may not call for institutional change. They provide skills, resources, and strategies for political and community engagement (Minkoff, 1995).

Furthermore, professional organizations also typically have highly skilled staff and leaders who can work with other similar institutions to obtain external resources from elite donors (Hernandez, forthcoming). Over time, these external ties become dependable long-term sources of relief. External donors and organizational supporters can create a formal network of churches, foundations, banks, universities, small businesses, and government agencies to obtain resources and legitimacy (Knoke, 1990).

H2: The resource mobilization index is significant for the recovery time for community aqueducts

Research Methods

Identifying the Population

I surveyed stakeholders involved in managing community aqueducts in Puerto Rico about their water management process and experiences with disaster recovery. The target population consisted of operators, community members, or local municipalities operating the aqueduct. The sample frame was obtained using a Puerto Rican Department of Health (PRDOH) report that pinpoints the relative location of registered community aqueducts, the name of the aqueducts, and other information related to them. The survey was sent to all 241 aqueducts, hoping to get information from as many of them as possible. This database of community aqueducts changes every year, meaning that aqueducts can be added or dropped; at the time of the survey, there were 241 registered community aqueducts. In this database, each community aqueduct had one associated contact person, so it was assumed that each person in charge represented the whole aqueduct. However, a unique code was added to each survey to ensure no more than one representative for each community aqueduct to avoid duplication.

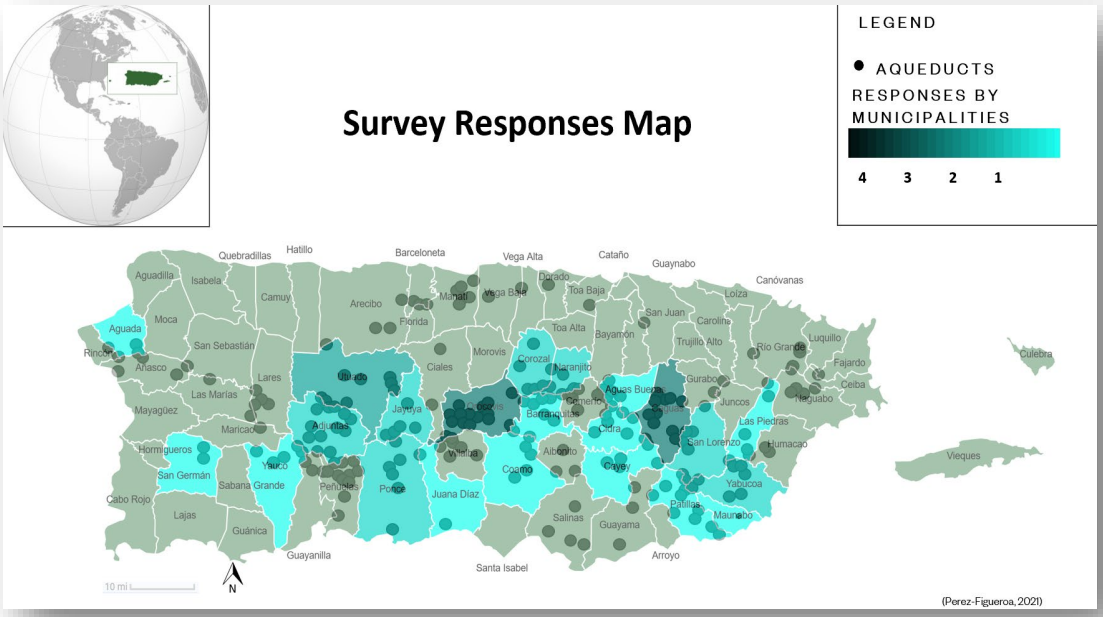
Participants were invited utilizing a combination of regular mail and email (Berry et al. 2003). This mixed-mode strategy was used (Dillman, 2000; Schaefer & Dillman, 1998) because

aqueducts sometimes lacked access to computers or WIFI. Therefore, regular mail was the preferred primary method. Participants took the survey between July and October 2021. An invitation was sent to explain the research using Dillman's (2009) approach to improve responses. In those invitations, the participants' names and the names of the aqueducts were used. The explanations were signed by the Principal Investigator (PI). Participants were invited to complete the survey using Qualtrics Survey Software. An addressed return envelope was also included with prepaid first-class postage, to which aqueducts could send handwritten answers. The invitation also had a phone number for questions or concerns. Providing this number helped to increase the number of survey respondents. The team followed up via email two months after the survey. Initially, it was intended to collect the data two months after they were sent out, but the survey period was extended to five months because of the rural locations and delays with the local mail.

Before administering the survey, a pilot version was conducted with five stakeholders. The survey was sent to two community aqueduct leaders, two government officials, and one grassroots organization representative. Piloting the survey ensured its language was grounded within the communities' experiences and context. The survey was conducted in Spanish since participants are Spanish speakers. Of the 241 surveys sent, ten were returned unanswered due to invalid mailing addresses, and 39 where completed, yielding a response rate of 16.9%. In addition, 23 responses were received through regular (response postage was provided) mail and 16 responses used the online version of the survey. The response rate is consistent with surveys with similar organizations (Hager, Wilson, Pollak, & Rooney, 2003: Fu, Coopper, Shumate, 2019). Out of the 43 municipalities that have community aqueducts we receive responses from

26. See below a map highlighting municipalities' responses; the darker the color, the more the responses.

Figure 4: Survey Response Map



Measuring Resource Mobilization (RM) and other outcomes variables

The final survey instrument had five sections:

1. Aqueduct Demographics (e.g., name, year in which it was registered)
2. Questions regarding how the community aqueduct can mobilize resources (e.g., how easy it is to mobilize your community)
3. Questions regarding how decisions are taken in the aqueduct (e.g., does your organization consider financial decisions to be collective decisions)
4. Question regarding the recovery process (e.g., how long it took to regain power)
5. Questions regarding resilience (e.g., how you define resilience under a disaster context)

Some questions were explicitly developed for this survey. Others were adapted from a 2019 technical assessment created after Hurricane María to provide a benchmark for the conditions of community aqueducts ("Non-PRASA Database", 2019). Some were taken from a capacity survey conducted by Bosque Modelo de Puerto Rico in 2019 (Bosque Modelo de Puerto Rico, n.d). I combined McCarthy and Wolfson's (1996) theory with Aldrich's (2012) to operationalize

resource mobilization, which highlights three distinct features of mobilization; (1) agency—what difference does the individual make, (2) strategy—how collectives can reach an objective, and (3) organization—variation in the organization of the group activities. While their argument is comprehensive, resource mobilization features can be applied to another context, especially when trying to understand the flow of resources from collective organizations under a disaster context. Daniel Aldrich (2012) highlights how collective actions and social capital through networks facilitate the flow of resources.

The survey used six Likert-scale questions to measure different components of RM (Table 1). A resource mobilization score (RMS) was calculated by taking the mean of the six questions. The score interpretation is straightforward: the higher the average, the higher the resource mobilization score. Each question demands the participant to have a relative notion of how 'fit' the community is to complete specific objectives; as such, the RMS can be considered an indicator of the community's collective goals. The resource mobilization score was tested for reliability using Cronbach's alpha (1951), with $\alpha = .80$.

Resilience was operationalized as the time to recover post-disaster. The United Nations Office for Disaster Risk Reduction (2007) defines disaster recovery as "the restoration, and improvement where appropriate, of facilities, livelihoods, and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors." Because recovery is critical for any resilience strategy, recovery time is used as a proxy for resilience. The disaster recovery time is an aggregated measure (calculated in months) of time to operate after Hurricane Maria, regain power, and restore gas station services after Hurricane María.

Measures of social capital were included in the OLS models to observe their effect on resource mobilization and recovery time. Aldrich (2012) and Roque et al. (2020) highlighted that

social capital is critical for post-disaster recovery. The following variables were measures of social capital. Those variables were: participation, total NGOs working with community aqueducts, decision-making approaches, the number of faith-based organizations, and the percentage of women participating in community aqueducts. These last two variables were salient for the recovery of Puerto Ricos communities (Sledge and Thomas, 2019; Guilbe-Lopez, 2021)

Besides community characteristic variables, the models also included variables that focus on the role of the built environment (e.g., distance to critical infrastructure). Infrastructure service disruption can impact disaster recovery, especially long-term (Mitsova et al., 2019; Barabadi & Ayele, 2018). Below is a sample list of the variables measured in the survey, including examples of the theory used to create them with their corresponding survey questions.

Table 5: Survey Measuring Variables

Table 5. Survey Measuring Variables	
Variable Overview	**Associated Survey Question**
Resource Mobilization (McCarthy and Wolfson (1996; McAdam, 1999; McCarthy & Walker, 2010)	Is mobilizing the community an easy task for your aqueduct?
	Can your aqueduct mobilize resources easily?
	Can your aqueduct execute plans easily?
	Do community members participate in the decision-making process of the aqueduct?
	Does your aqueduct foster community participation in the decision-making process?
	Have you participated in any program to obtain technical assistance?
Resource Capacity (Fernandez-Gimenez et al., 2015; Doan & Shaw, 2019; Sharpe, 2006)	How many staff work in the community aqueduct?
	Has the aqueduct undergone any upgrades?
	Who do you rely on most to help you in the aftermath of a disaster?
	How many women collaborate in your aqueduct?
	How often do you participate in community activities?

Social Networks (Aldrich, 2012; Schellong, 2007; Varda et al., 2009)	How many faith-based institutions are working with the community aqueduct?
	How many organizations are working with the community aqueduct?
Recovery (Olshansky & Johnson, 2014: Olshansky, 2018; Tormos-Aponte et al., 2021)	What percentage of your community is built with concrete?
	After Hurricane María, how long did it take to get the aqueduct running again?
	How long did it take to regain power?
	After the events of the 2020 earthquake, how long did it take to get the aqueduct running again?
	How long did it take to regain gas services?
Disaster Resilience (Aldrich, 2012; Traynor, 2018; Moech & Tyler, 2012)	How do you define resilience?
	Do you think your community is resilient?

Water Governance (Boltz et al., 2019; Feldman 2017; Vos et al., 2020)	Which of the following best describes the way that your organization makes decisions?
	• For financial matters
	• For repairs
	• For accessing fund
	  ○ Everyone in the organization makes the decision (consensus)
	  ○ The director/president makes most of the decisions (top-down)
	  ○ The person closest to the task makes the decision (distributive)

Data Cleaning and Analysis

Data cleaning included transforming the questions on a Likert scale[16] to match the 0-5 point scale. In four cases, participants from the same aqueduct answered the survey online and through regular mail. For these cases, an average was drawn on the answers to create a single response by the aqueduct. Data cleaning also included adding new variables to the data set and

[16] This survey employed a 0-5 Likert scale—this adaptation has proven to keep participants engaged (Chyung et al., 2017) even when there is research against using a shorter version of the original Likert scale, which uses a 0-7 scale (Finstad, 2010; Cummins and Gullone, 2000).

combining some of the responses to aggregate recovery time. Some of these added variables included: Aqueduct Served Population, among others.

Each hypothesis was tested using an Ordinary Least Squares (OLS) regression. Regarding Model A, the outcome variable is *Resource Mobilization*, and predictor variables are networks and participation. Concerning Model B, the outcome variable is aggregated recovery time, with *RM* as the primary predictor variable. Control variables include different decision-making approaches, total population served by aqueducts, funds obtained, total people working in aqueducts, total faith-based working with community aqueducts, and percentage of women working in aqueducts. Analysis was completed using Microsoft Excel Data Analysis Tool.

Results

Descriptive statistics

Here I present descriptive statistics for each variable; the resource mobilization score ranges from 1 to 5. Regarding the sample size for each variable, significant variation can be seen—as a result, there are some variables in which data is skewed.

Table 6. Survey Descriptive Statistics

Variable	*N*	*Min*	*Max*	*M*	*SD*
Total Served Population	39	38	2268	413	477
Drinking-Water Violations	39	3	421	181.31	127
Total Woman Working in Aqueduct	39	0	6	2	2
Total People Working in Aqueduct	33	0	33	6	3
Resource Mobilization Score	35	1	5	3.80	0.82
Distance to Gas Station (Minutes)	31	2	45	14.35	10.05
Distance to Hospital (Minutes)	30	5	60	23	13.57
Funds Obtain After Hurricane Maria	26	0	109250.00	31526.99	30775.44
Trusting Networks	31	0	4	2	1
Total Faith Based ORGs	30	0	5	1.76	1.27
Total NGO Working in Community	31	0	3	1	1.06

This table gives us an idea of community aqueducts' characteristics. The size of the community aqueducts can vary significantly, from those that serve water to 25 families to systems that provide water to more than two thousand people. Size variation has implications for managing them, as more extensive systems have more physical components that often complicate their operation. In terms of who are the people involved working the aqueducts, most aqueducts reported having an average of six people. Still, the maximum of people working in an aqueduct was 33. Personnel working with community aqueducts is often not paid, and most people volunteer their time. Because most aqueducts obtain revenue from the water bill, most aqueducts with paid personnel come from larger systems. Participation of organizations working with community aqueducts, including faith-based ones, was very similar as their mean was one and close to one. Some participants reported having access to a maximum of four types of social networks (family, neighbors, friends, government), while the average was two. Participants reported having shorter commute times to gas stations than hospitals or health clinics regarding distances to critical infrastructure. Funds obtained in the aftermath of Hurricane Maria varied considerably; the average surpassed the 30k mark—essential to notice that most of the participants who reported having applied for found were able to obtain in even if it took more than three years to receive them. Finally, regarding the resource mobilization score, even when the average was 3.80, most community aqueducts had some degree of resource mobilization in their organization.

Some of the variables used on the models were categorical; see below their summary.

Table 7. Summary of Categorical Data[17]

Aqueduct Energy Type	n	Main Decision Approach	n	Percentage of Houses Build with Concrete	n	Participation	n
Gravity	11	Collective	16	81-100 %	18	No Participation	5
Solar	3	Individual	15	61-80 %	13	Little Participation	20
Electric	16	Closest to Task	1	41-60 %	2	Lot of Participation	6
Electric/Solar	9	Mix	1	0-40%	0		
Total	39		33		33		31

After hurricane Maria, many aqueduct users realized how physically vulnerable their aqueducts were and started investing in solar infrastructure. While most participants reported that their systems were powered by electricity, many have solar systems in case of power outages, and others have their mini solar grid. Aqueducts run by gravity were least affected by power outages after Hurricane María. Still, many participants reported that aqueducts powered by gravity tended to have more drinking water violations. There was a virtual split between aqueducts that approach most decisions collectively against those taken by the president or the person in charge. When I disaggregated decision approaches, I discovered that decisions related to repairs and applying for funds were taken by the person in charge, even if most decisions were taken collectively. On the contrary, most aqueducts took decisions collectively when making a financial decision. When it came to the built environment, most participants reported that their houses were built out of cement; infrastructure vulnerability impacts the recovery process and overall resilience. This last variable was used as a proxy for financial vulnerability. Finally, most

[17] Not all this categorical made into the model's final version, but they are critical to understand the aqueducts characteristics

aqueducts reported some participation or many participations in their communities. Community participation is critical for building and maintaining social ties through time and under disaster conditions.

Model Results

Tables 3-4 present the two OLS model results to assess different elements to affect the aqueduct's resource mobilization and disaster resilience capacity. According to Model A (Table 3), an aqueduct's resource mobilization increased the more frequently they participated in the community ($B = 0.44$, $p = 0.01$) and the more networks they participated in ($B = 0.24$, $p = 0.03$). Furthermore, the resource mobilization score decreased as more women participated in the aqueduct ($B = -0.18$, $p = 0.03$). Additionally, resource mobilization increased as the number of faith-based institutions increased and the number of funds obtained after Hurricane Maria increased.

Table 8. Model A—Resource Mobilization

Variables	***Model A***	
	B	***SE***
Aqueduct Population Served	-0.0004	0.00
Total People Working in Aqueduct	0.04	0.04
Percentage of Women Working in Aqueducts	-0.01**	0.003
Funds Obtain After Hurricane Maria	7.27E-06**	3.57E-06
Total Faith-Based ORGs in the Community	0.17**	0.08
Networks in Which They Trust	0.24**	0.10
Total NGOs Working in the Community	0.0008	0.09
Participation Frequency in Community	0.67***	0.15
n=20 *p < 0.05. **p < 0.01. ***p < 0.001.		
R Square=0.78		

According to Model B (Table 4), recovery time decrease as the social network ties increased (B = -2.47, p = 0.02). Differently, the more decisions were taken collectively the recovery time decrease.

Table 9. Model B—Disaster Recovery

Variables	*Model B*	
	B	*SE*
Average Time to Critical Infrastructure	-0.04	0.10
Total Faith-Based ORGs in the Community	-1.02	0.95
Networks in Which They Trust	-2.47**	0.06
Total NGO Working with Community	-0.92	0.75
Participation	-0.72	1.73
Main Decision Approach	2.93**	1.60
Resource Mobilization	1.65	2.66
Percentage of Women	0.05	0.04
n=20 *p < 0.05. **p < 0.01. ***p < 0.001.		
R Square=0.58		

Discussion

In interpreting these results, I also include data from my experience providing workshops, observations, field visits, and interviews with community aqueducts and related personnel collaborating with them. More than 50 hours of interview data were collected by shadowing community aqueduct operators and observing their day-to-day activities.

Community Participation and Networks Lead to an Increase in Resource Mobilization

Community participation was strongly associated with resource mobilization (Table 3); this means that participation from operators in the communities where community aqueducts are located was critical for the aqueduct's capacity to mobilize resources. This result is associated with scholarship highlighting participation as a significant factor in recovery process after a disaster (Wolensky, 1983). This result is aligned with resource mobilization theory that underscore how participation is one of the critical components that impact resource mobilization (Johansson et 2009; Muniu et al., 2018). Participation ensures that the people affected by a problem are involved in defining the problem, planning and taking steps to resolve it, and establishing structures to ensure that changes are maintained (Thompson and Kinne, 1999). Furthermore, in water systems, community involvement can lead to participation in the planning, implementing, and monitoring of critical resources mobilization functions (Sara and Katz, 2004). It was also observed that the operator's participation led to the integration of community aqueducts in the fiber of the communities. Those well-integrated aqueducts were doing better in resource mobilization capacity or drinking water compliance and, to some extent, could recover quickly in the aftermath of Hurricane María.

Another significant variable within community participation was the percentage of women working on aqueducts. The variable total number of women in the aqueduct negatively affected resource mobilization. The negative coefficient for the variables total women working in aqueducts means that the more women participate in the aqueduct, the more resource mobilization decreases. While the scholarship I reviewed argues that physical resources and community participation are critical for women groups' sustainability (Collins & James, 2018), it

does not explain why the presence of women in an organization might affect its resource mobilization. However, a Report Published by Oxfam in 2018 addresses the impact of Hurricane Maria on WASH (Water Access, Sanitation, and Hygiene) practices in rural communities in Puerto Rico. The report found that mental and psychological health can be impacted by increased concerns about water availability and limited water resources for different family members, especially women. It also highlighted how women are more likely to look after relatives and sick relatives, which increased the women's workload after the hurricane (Smyrilli et al., 2018). These elements can potentially affect women's day-to-day activities in the aqueduct and, as a result, impact their resource mobilization capacity.

Additionally, qualitative data collected for this study revealed, how institutions and community members made the operation of aqueducts harder when all of members operating the aqueduct were women, which ultimately affected their resource mobilization: "*I am telling you when they see a woman, they make it harder for us, whether that is in our community or a government agency*" (Community Aqueduct 20, translation by author).

Another variable that impacted resource mobilization score was the presence of faith-based organizations. In this sense, the findings of this research align with previous results that highlight the importance of faith-based organizations in the disaster aftermath of Puerto Rico (Orengo-Aguyo et al., 2019; Santos-Burgoaet al., 2021). Rural areas in Puerto Rico tend to have a high ratio of older adults, many residents with poor health conditions, fewer economic resources and opportunities, and inadequate health care (Henning-Smith, 2020). This is compounded by the limited investment of the local government in these spaces. Still, in these spaces, faith-based institutions sometime provide the only means of social services. Many of these institutions were established early to evangelize and spread their faith, eventually

becoming beacons of the community. However, faith-based institutions can become sources of tension that can affect the operation of a community aqueduct, especially when different denominations argue for implementing different objectives in a community aqueduct.

The last variable that significantly affected resource mobilization was funds obtained after Hurricane María. This result means a positive relationship exists between aqueduct that obtained funds and aqueduct with high resource mobilization capacity. These findings are supported by a theory that underscores that the more resource mobilization capacity an organization has, the more financial resources it can obtain (Makhanu, 2007). Still, we do not know how funds were obtained or by which mechanism. We only know they were able to obtain it. After Hurricane Maria, many NGOs supported community aqueduct, and those who qualified to obtain aid benefited from resources. Typically, aqueducts benefited from those with a higher resource mobilization capacity. Furthermore, Community involvement may increase trust among local officials and residents, increase the government's knowledge of community priorities, and help residents access federal and state aid (Rosas et al., 2021.p1). Still, the funds obtained variable should be approached with caution because even when some aqueducts had obtained funds, some were unable to access them or waited more than two years to get them.

Social Networks Lead to a Decrease in Recovery Time

Social networks were strongly associated with shorter recovery time (Table 4). Resource mobilization theory highlights the importance of social networks in enabling collective action and accessing resources. Furthermore, interviewees highlighted how family, friends, and neighbors' networks were vital in recovery. Especially to be able to access resources. For example, one community leader had ties to the local municipality and used those ties to the municipality to access resources for their community: "After hurricane María, people from the

mayor's office came to find me because I was the only one who knew how to fix a power generator. After fixing the power generators, I saw an old one lying around, and I asked if I could take it for my community, and they said, sure, no problem". (CommunityAqueduct3). The quote highlights how even when the main objective was to help the people from the mayor's office, he could use those connections to access resources he eventually used to help his community.

Local-level networks are vital in community resilience efforts for response and recovery to environmental disasters (LaLone, 2012). However, these community aqueducts and their social services have received limited attention from rural development advocacy groups (Fedinick et al., 2017 in Arce-Nazario, 2018) and reports from regulatory agencies (Arce-Nazario, 2018). Nevertheless, the sense of pride and agency is still present. The effectiveness of the human networks required to manage the generators successfully and the residents' water usage under these conditions also reveal the extent of the social capital in these communities (Arce-Nazario, 2018). Furthermore, residents involved in the operation of community water systems developed the networks to reach governmental and nongovernmental agencies for aid and supplies during the crisis (Arce-Nazario, 2018). The previous section discussed how networks were critical for resource mobilization (Table 4)—with that result; it was not identified how one impacted the other; only a positive relationship was observed. It can be inferred that resources were available through networks. Social networks were vital for those community aqueducts that recovered faster, mainly because they access available resources at the local level (LaLone, 2012). Resource mobilization scholarship highlighted the role of reciprocity as a factor that impacts disaster recovery. In Puerto Rican, social structures from family and church come into play in times of risk, uncertainty, and struggle (Roque et al., 2020). After Hurricane Maria, a

pattern of how communities and families shared community reciprocity was set up in rural communities [such as those where aqueducts are located] to survive and cope with risks and disaster conditions (Roque et al., 2020). When disasters or hard times struck, families in communities supported and helped one another as a regularized norm of the way of living (LaLone, 2012).

Decision-Making Approaches Affected Disaster Recovery Time

The decision-making variable was significant for the recovery time. This variable is measured if decisions are mainly taken collectively and/or by the person in charge. Water governance brings forward the importance of decision-making processes for effective water management. Water governance refers to the social relations and systems that establish water services and distribution procedures (Hall & Rogers, 2003; Pahl-Wostl, 2015). Ostrom et al. (1961) argue that polycentric governance [like those of the community aqueducts] brings greater collaboration, increasing the adaptive capacity of governance systems and bringing about greater resilience. For example, Corcovada's community aqueduct approach of creating a decentralized electrical microgrid facilitated the process in which residents could operate their aqueduct again after the event by having solar panels and a backup power generator (Asencio-Yace, 2020). At the same time, there were instances in which community aqueducts that employed a top-bottom governance approach translated into resources to overcome extreme events like Hurricane Maria; this was the case for many aqueducts: "Because I am mainly the only person operating the aqueducts, I took the decision without consulting with anyone, in the end, time sided with me, it was the best decision" (CommunityAqueduct5).

The variable collective decision was significant for recovery time. However, this finding should be interpreted with caution mainly because there was almost an even distribution between

aqueducts that took most decisions collectively (16 participants) vs. those aqueducts in which the person in charge took most of the decisions (15 participants). Also, there were no virtual differences between decisions regarding repairs and applying for funds; the person in charge or the president decided most. However, things differ when the decisions had to do with financial decisions—must aqueduct took decision collectively when having to do with finances.

Resource Mobilization had no Impact on Disaster Recovery

I hypothesized that resource mobilization would affect recovery time; however, this was not the case. Some researchers argue that preexisting integrative community structures are vital in mobilizing resources post disasters (Wolensky, 1983; Bhandari, 2014). Although many of the community aqueduct stakeholders who participated in the survey were representatives of old aqueducts[18] with strong community ties, even with previous community infrastructure, it did not appear to affect recovery time. Nevertheless, an essential portion of participants were more recent aqueducts. A possible explanation may be that even though old aqueducts (with previous social infrastructure) were present in my sample, their effect was not powerful enough to be significant.

Even when resource mobilization was not significant for disaster recovery, one interviewee mentioned the importance of being able to mobilize people from the aqueduct, especially to learn how to operate it:

> "*After Hurricane María, an NGO came and built a new state-of-the-art aqueduct in a community I know. Not only they did a bad job in the construction, but no one trained community members to learn how to operate it or identify the organizational component that would ensure their operation through time. As a result, that community has a $20,000 structure sitting while they are still experiencing drinking water issues*" (CommunityAqueduct16, translated by author)

[18] Old aqueducts are those that were established between 1950 and 1960 are before, in which the aqueduct facilitated the creation of communities by providing water and other social services.

This story is repetitive in many community aqueducts. While many government agencies focus on the lack of resource mobilization on the physical infrastructure, there is little focus on its effect on its organizational component; one cannot work without the other.

Conclusion and Opportunities for Future Research

This study found that social networks and participation had the highest impact on resource mobilization. Furthermore, during the interviews, participants noted the importance of social networks in acquiring critical resources for their communities in the aftermath of Hurricane Maria.

Regarding my second model, in which recovery time was my outcome variable, the decision-making approach regarding decisions on water and networks was the most significant predictor variable. While the variable capturing decision approach was significant, in the future, I hope to observe the effect of the decision-making approaches on other variables governing the community aqueduct. This may be one of the limitations of this study. In the future, other mathematical models such as structural equation (SEM) specializing in evaluating multivariate causal relationships may provide a better fit to look at the decision-making process using a quantitative approach. Structural equations might provide a better fit to evaluate decision-making because they would test its many casual relationships. Moreover, it will access direct and indirect effects, especially because within the decision-making variable[19], there are nine sub-variables. With the current approach, I only could measure the effect of collective decision-making vs. single individual decision, but not the effect of the sub-variables, which SEM can provide. Another limitation was the small sample size; however, critical conclusions were drawn because

[19] Refers to the decision-making variable created for this paper

this is one of the first approaches with a survey on community aqueducts on disaster and water management in Puerto Rico.

While social networks matter greatly for resource mobilization and recovery time, we are not sure which mechanism impacts the other. Some of the different mechanisms that can be explored in the future are (1) strength of the strong ties, (2) strength of weak ties, and (3) position of the individual related to its network. Finally, future work can aim or dive further into what other factors besides resource mobilization can impact community aqueducts. For example, what is the effect of resource mobilization on water security? Water security is measured as a total of water violations.

Note

All interview quotes were translated from Spanish by the author

CHAPTER 4:DISASTER RECOVERY IN THE AFTERMATH OF HURRICANE MARIA: DIVERGENT UNDERSTANDINGS OF RESILIENCE

Introduction

For the last fifty years, people working in disaster-related social science fields have looked at how communities recover from disasters without external help (Manyena, 2006; Van Der Vegt et al., 2015; Capstick, 2018). Scholars use the term *resilience* to understand these underlying processes affecting communities recovering from disaster, conceiving resilience in knowledge, hazard management, and response systems (Nightingale, 2015). Notably, definitions for resilience vary widely, even when there is agreement on what it means; besides that, it is good (Luthar et al., 2000: Davoudi et al., 2012; Cote and Nightingale, 2012).

Although there is little consensus between fields on the definition, scholarship has generally considered resilience in relation to adaptation and response to environmental change that produces harm (Nightingale, 2015; Klein et al., 2007). Still, what resilience is, and who is responsible for gaining it or maintaining it through time is less clear (Nightingale, 2015: Manyena, 2006). One thing to note is that resilience is a phenomenon dependent on time (Haimes, 2009). For example, if a water system can withstand an earthquake of a magnitude three on the Richter Scale, it is resilient to an event on a scale of three or less, not that the system is resilient to all earthquakes. Research shows that trust, leadership, collective efficacy, social capital, social cohesion, community evolvement, existing norms, communication and information, and resource are critical for resilience. However, we do not know which of these can provide a resilient outcome or the degree of overlap between these factors (Maguire & Hagan, 2007). Therefore, looking at how disaster-affected communities understand resilience is critical in understanding the strategies they implement to face these events (White et al., 2015).

Another methodological issue regarding resilience is that there is no agreement on the best way to operationalize it (Cosco et al., 2017). As a result, resilience has been critiqued for being too abstract, apolitical, and ahistorical (Cote & Nightingale, 2012; Rodina, 2018). Moreover, even global policy discourses highlight the importance of managing climate change's impact on water systems (Salinas Rodriguez et al., 2014; Lafforgue & Lanouvel. 2015). Nevertheless, there is insufficient evidence to understand how the water sector and its systems will adapt to extreme events (Rodina, 2018), complicating how resilience is operationalized (Johannessen & Wamsler, 2017).

In designing human resilient systems, it is critical to consider water resource. Water serves as a master variable, mainly because of its connection to other systems; energy, agricultural, industrial, and urban (Boltz et al., 2019). Sound policy implementation and decision-making for [water] resilience requires a comprehensive approach that reveals interdependencies between these systems. As a result, many of these strategies have been driven by technological approaches to address questions of resilience. While technology certainly plays a key role in the capacity to adapt and manage water systems (Kiparsky et al., 2013), it has been shaped by the dominant cultural perspective and historically embedded urban water values that are expressed through institutional arrangements and regulatory frameworks (Brown et al., 2009). In turn, these dominant discourses can force visions of recovery focused on economic perspectives (Cox and Perry, 2011), overlooking the role of communities and their strategies to manage disasters.

This chapter aims to understand how perceptions and understandings of resilience affect recovery outcomes. For example, the conceptualizing of resilience as 'bouncing back' suggests going back to previous conditions as the preferable way to deal with catastrophes without

recognizing the implications of the change communities underwent (Manyena et al., 2011). On the other hand, the 'bounce forward' perspective may lead to intervention that addresses the root causes of risk (Manyena et al., 2019) and address social inequalities. Furthermore, designing policies assuming that all communities have the same 'capacity' to recover from disasters can lead to a skewed understanding of the problem, resulting in mismanagement. For example, if a community has an old well, the response could either be: 1) provide new infrastructure or 2) provide the infrastructure that goes hand in hand with community training accompanied by organizational skills. Option 2 helps ensure the system's continuous operation under climate change and hazard conditions because it considers the social infrastructure needed to support communities.

I focus on how resilience is understood by communities who have faced disasters and the implications of these understandings. More specifically, the following questions are investigated: How do diverse framings of resilience shape community aqueducts' disaster recovery efforts, and what is the role of water issues in operationalizing resilience for community aqueducts? These questions are important to understand resilience because recovery and disaster management policies that argue for the importance of resilience often fail to identify how to promote it. In short, operationalizing resilience has remained a challenge (Manyena et al., 2019). Furthermore, by analyzing divergent resilience understandings, I can detect discourse patterns that can shed some light on the way governments and non-governmental organizations (NGOs) define resilience and how this relates to the types of activities they undertook after the disaster. For example, different resilient understandings can reinforce or oppose the current socio-economic model of free-market capitalism.

To answer these questions, I examine Puerto Rico's case and cascading disasters from 2017

to 2021. I identified more than 100 published articles, including reports and newspaper articles about Puerto Ricans' resilience after disasters, especially after Hurricane María. Many publications depict resilience as a given, and few interrogate what it means to be resilient. However, an important part of them highlights water and/or access to drinking water as critical for resilience. Furthermore, they fall short in discussing how water can become the vehicle to operationalize disaster resilience. Still, rural community aqueducts in Puerto Rico have emerged as critical infrastructure by providing drinking water. Even when many operate outside drinking water regulations, they were the only drinking water sources in the aftermath of Hurricane Maria; thus, they were critical for communities' survival.

I drew upon the findings of 36 unstructured interviews and an ethnographic approach in 12 rural small-scale water systems in Puerto Rico to answer this article's research questions. These interviews were collected from October 2020 to October 2021, when I volunteered with El Bosque Modelo supporting community aqueducts. El Bosque Modelo is a grassroots organization that has worked with rural communities in Puerto Rico, including community aqueducts, for more than twenty years on economic and organizational development. Volunteering with El Bosque Modelo, I followed community-based research (CBR)[20] approach that included more than 100 hours of qualitative data, including visits, observations, meetings, and phone conversations. A CBR actively brings communities to participate by informing research questions and processes (Strand et al., 2003). The community-based approach builds on El Bosque Modelo's previous work in providing various workshops to community aqueduct on different topics (e.g., applying for funds, drafting organization mission statements.

[20] Originally this research seeks to use a Participatory Action Research (PAR)—it focuses on social change that promotes democracy and challenges inequality; is an iterative cycle of research, action and reflection but given time limitation to use PAR a CBR was used instead. CBR does not seek to challenge inequalities, still engage with participants equitably to trigger change

I first conceptualize the main 'realms' or fields used to understand resilience (Davidson et al., 2016; White et al., 2015) and then add political ecology perspectives to problematize how people understand resilience. I argue that we need to look at the political ecology perspective to understand the implications when resilience is defined as a process or an outcome. Even when resilience and political ecology stem from divergent epistemologies (Turner, 2014), I argue that political ecology can be used to advance the concept of resilience. Political ecology seeks to understand the differentiation of resource access across societies and individuals and how those variations and accessing resources affect their material conditions (Turner, 2014). Within the discussion of resilience fields, I add a section that discusses the implication of understanding the case of Puerto Rico employing set fields. The third section presents an overview of the methods. The fourth section presents the findings in conjunction with the discussion, grouping the understandings of resilience as 'outcomes' or 'process'. While the theory section considers that diverse understanding of resilience can be grouped mainly under those that describe resilience as an outcome or a process, the focus of the section is to understand how fields understand it, as these understandings drive how resilience is operationalized. I conclude with implications for future research and limitations.

Framing the Case Study: Puerto Rico's Independent Community Aqueducts

In Puerto Rico's rural areas, there is a hidden network of small water systems hiding in plain sight. These small water systems are not new on the island; they have been operating for more than 50 to 60 years. Even before Hurricane Irma and Maria, these community aqueducts provided the only drinking water sources for rural communities. After experiencing these catastrophes, scholarships continue to highlight their resilient capacity to overcome these events (Ruiz-Aviles et al., 2021; Arce-Nazario, 2018). Some community aqueducts have continued

operating under these dire conditions, providing drinking water for residents and neighboring communities. Even when government officials argue they are primitive, unsafe, and ineffective, they remain, in some cases, the only source of clean drinking water in Puerto Rico's rural communities (Arce-Nazario, 2018). Thus, community aqueducts become a critical case to observe how impoverished communities with limited political power can become resilient and guarantee clean drinking water services.

The Environmental Protection Agency (EPA) defines small water systems as those that supply drinking water to less than 3,300 people (Alicea-Martinez & Rios, 2016). These systems are known on the island as non-PRASA because they fall outside the main public water utility, Puerto Rico Aqueducts and Sewer Agency (PRASA). There are currently 241 of these systems, and they provide roughly 5% of the island's water supply, which translates into supplying drinking water to approximately 150,000 people. Many of these systems originated because of a state's lack of policy to provide water to rural communities in Puerto Rico. These aqueducts can vary by size and power source; most operate with electricity, others use solar energy, and others operate by gravity. Additionally, around 68% of aqueducts (Ruiz-Aviles et al., 2021) obtain their water from wells and aquifers, while the 32% obtain their water from surface sources, such as rivers and small creeks.

Community aqueduct organizational structure also varies. Many of them are operated by a board that includes presidents, vice-presidents, treasurers, secretaries, and other supporting personnel. While this is the most typical structure, some aqueducts are operated entirely by 2-3 people. Their limited personnel operating their aqueduct can impact their capacity to withstand an extreme event and comply with official drinking water standards. Typically, those aqueducts run by fewer people have low levels of formal education and a high poverty index. Still, there

has been an effort to support these systems and get them in compliance. Diverse sectors such as government agencies, non-governmental agencies, technical organizations, churches, academic researchers, and private donors have participated in these efforts. Some of these efforts include providing technical workshops and funds to improve their physical and organizational infrastructure.

Puerto Rico and its small water systems must comply with the EPA Clean Water Act as a U.S commonwealth. Compliance with the Clean Water Act requires turbidity, bacteria, and heavy metal tests. In 2015, only half of these systems complied with drinking water regulations (Alicea-Martinez & Rios, 2016). Aqueducts that obtain water from wells typically have better water quality because the soil works as a natural filter. While they have a better water quality than surface water aqueducts, they must invest in primary water treatment methods. Most community aqueducts use chorine and or microfilters as their primary method to disinfect the water. To ensure they comply with these standards, federal and local agencies (e.g., Puerto Rico Health Department) require community aqueducts with monthly and yearly water quality tests. More recently, community aqueducts have complained that these tests are too onerous for them and have forced them to decide between paying the power bill to keep running the system or complying with water standards.

Due to communities' high poverty levels and remote locations, these systems are typically dilapidated, operating with many deficiencies, as it is difficult to obtain and transport construction materials (Ruiz-Aviles et al., 2021). As a result, many of these systems can be particularly vulnerable to disaster. Before Hurricanes Irma and Maria, many of these systems operated outside drinking water regulations (National Resources Defense Council, 2017). The storms impacted the system's capacity to comply with water drinking regulations (Ruiz-Aviles et

al., 2021) mainly because not all community aqueducts had access to power generators that would allow them to keep operating. Even when the electrical power is back, high energy costs complicate their operation. Two years after the storms, a series of earthquakes shook the island—for three months, the island had (Van Der Elst et al.2020) aftershocks reaching up to 6.5 in magnitude. These earthquakes affected community aqueducts, especially those located southwest of the island. Earthquakes' effects on aqueducts included damage to infrastructure, including the movement of the water vein[21] used to extract water, that in some cases resulted in spending funds to construct a new well. One year after the earthquake, the COVID-19 pandemic came, affecting the decision-making processes and water bill payments.

Some of these small rural aqueducts had solar panels and were already operating within days of the storms. Also, under Hurricane Maria, they serve as shelter and first aid facilities. Furthermore, reconnecting their water services has served communities to reconnect with each other and build community. Finally, these aqueducts remain a critical case to observe how these communities have been able to keep providing water services under cascading disasters.

Literature Review: Dissecting Resilience

Two perspectives have emerged from the literature to conceptualize resilience (MaCcubbin, 2001). One focus describes resilience as a positive outcome in overcoming stress from traumatic events (Rutter, 1990), while the other focuses on resilience as a process by "describing resilience as a capacity for successful adaptation in the face of hardship" (Garmezy, 1991: Glantz & Sloboda, 1999). Different camps or fields have used these perspectives to advance resilience. See below (**Table 10**), which places different fields concerning the debate resilience as outcome or process.

[21] Is water that flows underground between layers of rocks

Table 10. Resilience Perspectives

Resilience Fields or 'Realm' Under Environmental Hazards	
Resilience as an Outcome*: go back to normality and surpass obstacles*	***Resilience as a Process—****recognizes the human role in disasters, acting, having plans, building the capacity to implement a plan, and sharing information about recovery are critical steps to enable resilience*
Fields: **Ecological Resilience**, **Social-Ecological Resilience,** and **Urban Resilience**	Fields: **Disaster Resilience** and **Community Resilience**

It is crucial to highlight that even when these resilience perspectives are interrelated (e.g., resilience is an outcome triggered by certain processes), they have been defined as distinctive one from the other (MaCcubbin, 2001). Thus, we must first understand how each field or camp defines and analyzes resilience.

In this section, first, I analyze the concept of resilience under environmentally hazardous conditions to understand how different 'fields' positions depend on how they define resilience. These fields are ecological resilience (ER), social-ecological resilience (SER), urban resilience (UR), disaster resilience (DR), and community resilience (CR) (Davidson et al., 2016). Secondly, can those frames be used to explain the case of Puerto Rican communities under disaster conditions, including their limitations? Looking at these domains to study the case of Puerto Rico makes sense on two fronts. First, they highlight different variations of resilience in under extreme weather conditions. Second, they serve to understand the variation in the definition and its implication for the island's recovery process. Next, I use political ecology theory to problematize the concept and explain how systemic issues can perpetuate inequalities by employing notions of resilience that perpetuate communities' unjust conditions. The political ecology lens will be mobilized to understand the implications of using resilience as a process or outcome in the

discussion section. However, because political ecology also focuses on the diverse ways power is exercised within a society, it allows us to observe alternative configurations of community strategies that guarantee future access to drinking water. This alternative configuration can challenge normative water usages that prioritize big water utility grids against community approaches (Swyngedouw et al., 2012).

Resilience can be considered a theory and, as such, can be adjusted to multiple epistemologies (Luthar et al., 2000: Davoudi et al., 2012). While the word resilience is contested (Cote and Nightingale, 2012), it has become the buzzword to analyze climate-related impacts (Hill & Kakenmaster, 2018; Meerow, S., & Newell, 2016). Scholars use this word to describe how communities manage and cope with crises (Garmezy, 1991; Luthar & Zigler, 1991; Masten, Best, & Garmezy, 1990; Rutter, 1990), but rarely do they explore the implications of using this term or how it is shaped by the communities who use it.

Its theoretical origins are rooted in social-ecological systems and their capacity to adapt to change (McEvoy, Fünfgeld, & Bosomworth, 2013; O'Hare & White, 2013; Sudmeier-Rieux, 2014). Furthermore, there is little understanding of what it means to be resilient; beyond the general agreed-upon notion that it is good (Davoudi et al., 2012). However, social theorists have criticized how ecological models are applied to social structures, including the general lack of focus on issues of politics, power, and equity (Cote & Nightingale, 2012; Cretney, 2014; Evans, 2011; MacKinnon & Derickson, 2012; Weichselgartner & Kelman, 2015). These authors question different views of resilience by asking "resilience of what for what?" and "resilience for whom?" (Carpenter et al., 2001; Lebel et al., 2006; Vale, 2014; Meerow & Newell, 2016).

Ecological and Social-Ecological Resilience

Ecological resilience (ER) began with Hollings (1973). Crawford Stanley Hollings described the capacity of ecological systems to endure or absorb change while maintaining their structure and function (Davidson et al., 2016). It was used mainly to understand the dynamics between biological organisms and their physical surroundings, specifically how unpredictable a change could occur within different environments. Let us remember that ecology is a branch of biology, and as such, resilience within this field came out of necessity to understand organisms that behave very differently from humans. Social-ecological resilience (SER) is also anchored on Hollings' ecological resilience work, focusing mainly on understanding ecological systems linked to humans (Davoudi et al., 2012; McEvoy, Fünfgeld, & Bosomworth, 2013; O'Hare & White, 2013; Sudmeier-Rieux, 2014). Within the realm of SER, key terms have been developed, such as the capacity for adaptation and transformability (Davidson et al., 2016 in Folke et al., 2010; Gunderson, 2000).

Drawing from Hollings' (1976) understandings of resilience, and using the case of Hurricane María, Crisman et al. (2021) identified four general ecosystems resilience disturbances (resistant, resilient, alternative stable state, and collapse). These models are based on how a system (Puerto Rico) can react to a disturbance (Hurricane Maria). Crisman et al. (2021) highlight that human society's sustainability can be understood through the Water-Food-Energy (WFE) Nexus[22] and the importance of maintaining WFE stability. Ultimately this paper analyzes the impact of Hurricane Maria on the WFE and its implication for long-term recovery in different sectors (Environment, Infrastructure, Communities, and Governance). The paper

[22] Food-Water-Energy Nexus—According to the Food and Agriculture Organization of the United Nations, explain that water security, energy security and food security are link one to the other, meaning that any action in either of them can affect one another, or both of the other areas

concludes by saying that the island has shown incredible resilience toward the impact of cascading disasters; still, it stresses the importance of resources for local communities' empowerment and self-sufficiency. Even when the paper recognizes that in the case of Puerto Rico, its governance, colonial reality, and decision-making process can affect overall resilience, it focuses on the ability of ecological systems to go 'back' as a measurement of resilience. Still, Collazo et al. (2018) argued that even if a social-ecological framework is used, under climate change and urban sprawl conditions, diverse stakeholders must be included to ensure the successful implementation of resilient strategies.

Similar to Crisman et al. (2021), Zimmerman et al. (2020) argue that human systems[23] in Puerto Rico were affected by Hurricanes Irma and Maria and that anthropogenic impact also increases the frequency of hurricanes, ultimately affecting social-ecological systems and communities' livelihoods. Ultimately Zimmerman et al. (2020) note that finding ways of systematically linking storm intensity with diverse components of social-ecological systems on the island remains a challenge. Zimmerman's argument considers communities being impacted by disasters as 'systems'. It recognizes the implications of economic, social, and political factors combined with natural and physical resources that can determine how efficiently societies can manage disasters (Lopez-Marrero and Wisner, 2012 in Zimmerman et al., 2020). The article concludes by considering that social impacts have focused on short-term and relief efforts. It also indicates that future work should include the long-term effect of social impacts and the importance of understanding how recent storm management failures can be linked to long-term government relief efforts.

[23] Under ecology, human systems are defined as those govern by human actions (e.g., food policies, political systems, water management, among others)

While ER and SER's approach to storm disaster considers the importance of human systems in understanding ecological resilience, it recognizes that it has focused on the 'bounce back' perspective. This bounce-back perspective has tended to focus on recovery efforts and resilience in the short term (Manyena et al., 2011). Furthermore, it recognizes (at least in the case of Puerto Rico that future studies are needed to understand long-term relief efforts considering government failure and its effect on ecological systems. Even when ER and SER scholarships employed in Puerto Rico see stakeholder participation as critical, the question remains: does the apparent shift to include diverse stakeholders comes from a new epistemological understanding of resilience or from recognizing that we can only tackle climate change impacts through equitable collaboration. Either way, it would signal a change from traditional understandings of ER and SER that only focus on equilibrium to measure resilience.

Urban Resilience

Urban resilience (UR) is often referred to in the context of crises and is defined as a return to a pre-existing point of stability (Davidson et al., 2016). Under this approach to resilience, engineering and urban planning are the two main fields that use it. While under the UR, the engineering field mainly focuses on understanding how to resist environmental hazards' forces, shocks, or stress (Leichenko, 2011), under urban planning, UR focuses on how urban systems can adapt and adjust to changing influences (Pickett et al., 2004; Davidson et al., 2016; Rijke et al., 2013) including the role of technology in adapting. Additionally, within the field of planning, UR has focused on a view of equilibrium in the structures of the cities and their build environment (Pickett et al., 2004). This frame guiding objectives mainly focuses on addressing hazards from a structural perspective, focusing on the physical components to be managed to recover from extreme conditions. However, the equilibrium approach is still associated with the

modern era of the 20th century based on the premise of technology and science to meet economic needs. Still, in the second half of the 20th century, a non-equilibrium paradigm emerged, that chaos or non-equilibrium paradigm argued that cultural systems are variable, uncertain, and prone to unexpected change (Ahern, 2011). This last paradigm is vital to understanding resilience outside equilibrium in urban settings.

In the case of Puerto Rico, urban resilience has been defined as "making people, communities, and systems better prepared to withstand catastrophic events—both natural and human-made—and able to bounce back more quickly (The City Resilience Index in Yabe et al., 2021). More specifically, UR is a process in which urban communities, managers of infrastructure, and governments adapt to rebuild (Yabe et al., 2021). Yabe et al. (2021) noted that in the case of Puerto Rico, urban networks provided critical services (e.g., drinking water) and that there were interdependencies between physically engineered and socio-economic systems. Networks play an important role in connecting actors, learning, knowledge management, and accessing resources and support (Gunderson, 1999; Olsson et al., 2006 in Rijke et al., 2013). They also found that extreme weather events and disasters can provide opportunities to build 'back' better, improving the urban resilience of a place (Johnson & Olshansky, 2016). Still, other authors argue that this build 'back' better narrative is driven by colonizing narratives of resilience that have been used to displace communities (Myers, 2021). Jenny Myers (2012) further argues that reciprocal bonds can tie communities and that they maintain their connection to the place through 'community practices' (that can lead to resilient outcomes).

Johnson & Olshansky's study (2016) emphasizes inequalities as factors that negatively impact the mobilization of financial and technical resources to address disasters. The UR emphasizes the built environment and sees cities as whole systems with the ability to come

'back' to their previous state. However, in the case of Puerto Rico, it notes the importance of looking at communities' vulnerabilities because it can disproportionately cost disruption in the recovery and make this process slower (Yabe et al., 2021; Johnson & Olshansky, 2016). Also, UR has tended to expand from its original 'urban' focus to encompass other dynamics between societies and the built environment that have a spillover effect further from city centers.

The engineering field and its application of resilience on the island have focused mainly on two issues. First, many future projections on the built environment are not attuned to the actual population prediction, which impacts capital investments and long-term plans for recovery (Keenan & Hauer, 2021). The second issue concerns the island's impact on its fossil fuel dependency, triggering a movement to build solar systems and microgrids. The first issue points out how Puerto Rico is overestimating the nature of future beneficiaries of recovery when it comes to the infrastructure sector (Keenan & Hauer, 2021). The second issue highlight how pragmatic solutions anchored on communities building their solar grid can lead to "Self-Reliance Solar" or Solar de Autogestion. While Keenan & Hauer (2021) focused on the importance of accurate data to make verifiable predictions on the built environment, Krantz (2020) stressed the importance of organizing rural communities and self-reliance to improve their resilience in the physical structure. This last reference is critical in combining community participation perspectives and its implication for the built environment. Under our climate change condition, more communities on the island are re-evaluating their infrastructural resilience by incorporating democratic decision-making that leads to overall resilience (Asencio-Yace, 2020). As a result, new literature links infrastructure resilience issues with community issues (Davidson, 2015).

Disaster and Community Resilience

Like UR, disaster resilience (DR) has focused on an equilibrium approach driven by notions of stability (Davidson et al., 2016). Still, recent events like Hurricane Katrina in New Orleans have forced DR to move into a more integrated paradigm (Park et al., 2011; Djalante et al., 2013) that highlights how disaster resilience has the potential to allow the integration of diverse sectors of society in the disaster management process. As a result, the latest research on DR emphasizes the capacity of complex systems and communities respond well to extreme events (Berkes, 2007; Robertson et al., 2021) by building and sustaining social capital and social resilience (Davidson et al., 2016).

While community resilience (CM) is a distinct 'realm' (Davidson et al., 2016), it will be discussed jointly with disaster resilience. This is mainly because community resilience typically draws from disaster management while including psychological resilience (Berkes and Ross, 2013; Davidson et al., 2016). This psychological perspective is concerned at the individual level with how people cope with risks and catastrophes (Juliano & Yunes, 2014). More recent CM scholarships consider people's collective resources, also referred to as different types of capital (e.g., social, economic, political), to support them in managing catastrophes (Cutter et al., 2008; Davidson et al., 2016).

Anchored on psychological resilience, Ardila-Sanchez et al. (2019) provided a framework that identifies the social and cultural aspects of communities in which metacontingencies[24] may foster positive social change, impacting the collective well-being at a psychological level after hurricane María. For Ardila-Sanchez (2019), metacontingencies affecting disaster recovery are driven by the interaction between the US Congress and the

[24] Metacontingencies are used in psychological behavior to explain the social environments of groups in which their individuals can engage in diverse behaviors seeking a 'product' that has a demand

government resources connections to the island's residents. In a different way, Holladay et al. (2019) underscore how high levels of community resilience can be fostered and enabled by community projects such as agroecology (Brundiers et al., 2018) in Utuado. Community interactions that stem from community projects, in turn, can strengthen when communities' development is connected by economic activities that are just and fair (Choi & Sirakaya, 2006; Hahn & Nykvist, 2017). In their article, Holladay et al. (2019) describe how Tetuan Renace, a grassroots collective in Utuado, has brought diverse stakeholders to support their community preparedness plan for future extreme events through their strategic vision and business plan. In conjunction with Holladay et al. (2019), Macias et al. (2020) discuss how incorporating group storytelling in post-disaster research is a culturally sensitive practice that can promote resiliency among survivors. CR cases in Puerto Rico continue to follow the scholarship trend that highlights psychological components and community networks as ways to deal with catastrophes. More importantly, they underscore the participation of the community and their cultural component and identities in engaging with practices that can lead to resilience outcomes.

In Puerto Rico, urban resilience efforts have focused on building partnerships to cope with extreme events such as Hurricane Maria. Morales-Ramos et al. (2021) underline the role of nursing health in creating partnerships that strengthen patients' resilience. Nurses are critical stakeholders, especially in the island's current context of a shortage of health care personnel; plus, they encourage a sense of community, fostering the self-transformation of patients. Other spaces used to build partnerships were community gardens in Puerto Rico (McIlvaine-Newsad, 2019). They are critical in building cultural knowledge, leading to resilience as it allows communities to access the strength of one's cultural system. Similar to McIlvaine-Newsad (2019), Delilah Roque et al. (2020) focused on rural communities by discussing the benefits of

social capital for disaster recovery (Aldrich, 2012; Barone & Mocetti, 2014; Hawkins & Maurer, 2010; Islam & Walkerden, 2014; Nakagawa & Shaw, 2004) especially by supporting residents and neighborhood in gathering, reflecting on, and accessing information. Mobilizing resources through their networks was critical in building community resilience in the aftermath of Hurricane Maria.

Expanding Resilience Through Political Ecology

In the previous sections, I have presented the five 'realms' understandings of resilience and how they have been employed to examine Puerto Rico's case under disaster conditions. Even if different fields incorporate equity perspectives and the importance of community participation in defining resilience, it appears very superficial and limited at best. The way in which diverse frames of resilience have been used on the island point out how the field of resilience as a whole is distancing itself from traditional notions that prioritize balance and define resilience under an outcome's lens. However, traditional and normative resilience frameworks continue to have dangerous outcomes. The institutional notion of returning to a state of system stability, especially in colonial or postcolonial contexts, runs the risk of depoliticizing the very nature of reconstruction, as struggles to gain control over access to knowledge, information, and resources that are conflictive, exposing power asymmetries between the colonizer and the colonized (Borges-Méndez & Caro, 2019 p.15). Therefore, the push for resiliency must be approached with great caution. We want our buildings and bridges to be resilient, but do we want our communities to become well-adapted to structural (and infrastructural) violence. Each 'realm' presented its understanding of what it means to be 'resilient' under disasters, even if they are very similar. Still, none of those 'realms,' or at least their focus, is not to confront the complicated relationship between social, political, and economic dynamics that chape the

Caribbean context (Moulton & Machado, 2019), especially when the region has strong ties to its colonial past and systemic oppression.

Applying resilience theory strictly from the ecological perspective to explain resilience in the aftermath of a disaster has proven problematic (Aldrich, 2008: Grover, 2013; Joseph, 2013). For example, the ecological stance assumes all organisms would have the capacity to find balance in recovering from an attack. However, this assumption may not work well with humans (Davoudi et al., 2012: Joseph, 2013: Meerow & Newell, 2016). If this assumption were true to predict human resilience after an extreme event (e.g., disaster), communities would recover within days, which is not always the case. Furthermore, this assumption argues that all people have the same capacity to recover, overlooking different capacities for accessing resources. Additionally, these notions of resilience try to incorporate the word "adapt" to maintain existing systems and structures (Donoghue, 2019). For instance, how will people recover from a hurricane if the government does not provide the resources and policies to support these efforts? (Bonilla & Lebrón, 2019)

Using a political ecology frame, Luke (1977) argues that how a group perceives power may reproduce and reinforce power structures and relations; alternatively, it may challenge and subvert them. For example, power sets of the context allow the reinforcement or opposition of the ongoing economic liberalism and free-market capitalism of diverse sectors of society (Grover, 2013; Bonilla, 2021, Joseph, 2013). This approach obscures power relations (Fainstein, 2015) and implies resilient subjects must accept their fate as vulnerable subjects in the social world and upon whom the state imposes resilience (Sou, 2021. p16 in Evans & Reid, 2013). Consequently, divergent understandings of resilience are not created in a vacuum; they are rooted in our socio-economic structure, which is embedded in the distribution of power, wealth,

and resources. Moreover, this structure is continually shaped by ideologies, such as colonialism, nationalism, militarism, neoliberalism, and consumerism (Wisner et al., 2011).

Anchored on political ecology understandings, Bonilla (2019; 2020) argues that "disasters should not be understood as sudden events, but rather the outcome of long histories of slow, structural violence (Faria et al., 2020). That 'vulnerability' both social and environmental, is thus not a natural state but the product of racial-colonial governance[25]"(Bonilla, 2019, p. 1). This methodological approach situates acts of resilience within the colonial relations that characterize the United States−Puerto Rico relationship (Sou, 2021). Gemma Sou (2021) argues that to understand resilience under these colonial dynamics, we need to understand how people's acts of resilience are presented as acts of resistance to pursue self-determination and renounce their dependency on the United States for their everyday lives and disaster recovery. The author further stress how women in the domestic space enact resistance to this dependency. And finally, she emphasizes the importance of exploring resilience "from below" or from the 'ground', which exposes how state-centric definitions of resilience do not fit with how disaster-affected people define and enact resilience.

Material and symbolic reconstruction of the island requires a transformation that includes a sense of resilience that counters the narrative of going 'back' or maintaining the 'status quo.' It needs to mobilize Caribbean communities outside these pre-determined frameworks that work within the capitalist society (Moulton & Machado, 2019; Bonilla, 2020). Furthermore, financial and political elites have been able to create and maintain a hegemonic bloc that has been able to incorporate, co-opt and coerce great swathes of people into accepting its organizing principles and the underlying philosophy of adapting to the current conditions (Donoghue, 2019: Grover,

[25] Stress the co-constitutive nature of race and colonialism and foreground the importance of conquest and colonial outposts for the development of modern capitalism (Robinson, 2019)

2013). Opposition or resistance to that antiquated notion of resilience is also opposition and resistance to an elite or oligarchical notion of what would make a sufficient recovery from a disaster (Grover, 2013). In addition, oppositions and grassroots strategies are always among communities and must be investigated differently.

As we saw in this last section, mechanistic approaches to resilience have proven very limited in explaining how communities craft resilience from the bottom up, especially in Puerto Rico after Hurricane Maria. In Puerto Rico normative approach of resilience that can perpetuate unjust conditions has been primarily used as the official vision of 'resiliency' to ensure insurance markets and future property speculation (Molinari, 2019), resulting in community displacement in some instances (Shearer, 2012). For the island, a post-disaster future means more than repairing roofs and restoring streetlights; it also needs to address its deep inequalities and long colonial histories that have left some communities in the [permanent] state of vulnerability to future disasters (Bonilla, 2020). Defining resilience in a new light is imperative if we aim to integrate communities' strategies and necessities. These new understandings also require policy avenues that encourage local and regional strategies to bypass the island's colonial status limitations and address its structural disadvantages (Borges-Méndez & Caro, 2019).

Methods

Previous research on resilience typically captures how professionals measure it, rarely including community members' perceptions (Nightingale, 2015). Community discourses must also be included to assess these diverse resilience understandings. As a result, I employed a CBR approach, bringing front and center community knowledge and ensuring that communities lead the way in defining challenges and obstacles related to their resiliency. With this approach, I captured divergent understandings of resilience by employing a non-extractive research design,

prioritizing equity in engaging with community members. Before the formal research began, community members and the PI held multiple conversations to understand their concerns regarding recovery and its relationship to water issues, including how they saw themselves participating in this research. One of the elements that followed CBR principles was the co-ownership of any data produced for the Bosque Modelo. Also, part of the negotiation with community aqueducts included sharing research findings with community members in a format conforming to their needs once the research concluded. In addition, in conjunction with the Bosque Modelo, a series of workshops were developed for community aqueducts to improve their access to knowledge regarding sound practices for their community aqueducts and strengthen their organizational and equitable participation practices. After each workshop, feedback was collected to measure knowledge gain and gauge community understanding of the concepts. This step guaranteed that previous community objectives were covered during the workshops, and doubts and questions could be addressed.

The CBR approach included more than 100 hours of qualitative data. For this article, I draw most directly on 36 interviews conducted with individuals who work closely with community aqueducts, including small water systems personnel. While most of the findings are drawn from these interviews, I also include observations from an ethnographic approach on 12 community aqueducts. This ethnographic approach occurred as a part of a community-based approach with the grassroots organization El Bosque Modelo. El Bosque Modelo is an organization focused on the economic and social development of Puerto Rico's rural communities. Part of their work with rural communities has included collaboration and work with community aqueducts. As a part of my volunteer work with El Bosque Modelo, I created a

series of workshops for community aqueducts to support their organizational structure and help them obtain resources to improve aqueducts' physical and organizational structures.

During the interviews, participants were asked about their understanding of resilience in general and concerning water issues. These questions prompted participants to evaluate or provide their own definition of resilience, including the most critical element of being resilient in the face of likely or probable future environmental hazards. Most of these interviews lasted between 45 and 60minutes. Interviewee represented community aqueducts (n=15), non-governmental agencies or grassroots organizations (n=12), technical organizations (n=3), and governmental organization (n=6). Interviewees were from different municipalities. Most of them were either in San Juan (Puerto Rico's capital) or rural municipalities.

The ethnographic approach was conducted on 12 community aqueducts, most of them located within the regional scope of the El Bosque Modelo. Visits were conducted to observe their day-to-day activities and understand some of their challenges. Some of these visits range from a couple of hours to a full-day visit. Conversations with the aqueduct personnel included how they were built, how the community organizes around them, their experience managing the aqueduct under disaster conditions, their perception of the recovery process, and how they perceive their context and concerns related to drinking water.

While some of the interviews were transcribed and translated by the investigator, most were transcribed and translated by professionals. They were analyzed using a grounded theory approach (Glaser & Straus, 2017; Saldaña, 2021; Locke et al., 2015). In the first coding round, general themes were identified (meanings of resilience, disaster experiences, non-PRASA challenges, and non-PRASA assets, among them). Then, the second coding round was employed to improve the categories, ensuring they reflected the content. During these phases, coding

categories were adjusted, renamed, and or new categories emerged. Finally, a third-round focused on resilience, coding for how resilience was understood, and categorizing resilience as an outcome, process, or if a new category was needed—Eight codes for resilience were identified. Saturation was reached when no new resilience frames were identified. The software NVIVO 12.0 was used for the coding process. I used codes for Resilience, Disasters, Recovery, Mobilization, and Community for this article.

Findings and Discussion

Resilience in the context of community aqueducts can operate mainly in two ways, as an outcome or as a process (Manyena, 2006; Kaplan, 1999; MacCubbin, 2001). Although this distinction might sound trivial, it allowed one to understand and analyze how diverse definitions of resilience are employed on the ground. These distinctions can be traced back to each resilience 'realm'. In addition, I discuss here how resilience is enabled in the context of community aqueducts. This section includes observations and community storytelling, which helps us understand different perceptions of resilience, including those who fall outside the traditional 'realms' of resilience.

Resilience as an Outcome

Several interviewees use the language of 'bounce back,' move forward, or get back to normality to define resilience: "…[resilience] It is the capacity that the system has in the event of a disaster to go forward, continue in its function as a water system" (GovernmentInstituion_9). This argument was anchored on the capacity communities have regardless of the event. Even when other participants mentioned circumstances as key to resilience, they signal back the idea of resuming normalcy: "It is to resume normality, right, within the circumstances in which you are" (EducationalInstitution_10). In other instances, NGOs mentioned how coping was vital to

define resilience: “Well, resilience is literally the ability to cope with the condition that is, not necessarily adverse, but adverse to how you normally operate” (NGO_13).

It is important to mention that even when different institutions use the framework of ‘bouncing back’ or capacity to go back to normality and surpass obstacles (Manyena, 2016), there were not the only ones. Some community aqueducts had those same understandings: “It is the ability to return to... Even how it was before some event or phenomenon that affects stability. That is what I remember from the definition (CommunityAqueduct_2). Another aqueduct mentioned how: “Well, resilience, the ability to restore, return the aqueduct system to normal, right? That people have their water running again and receive quality water. That to me is resilience in terms of the aqueduct system” (CommunityAqueduct_12). This participant highlighted the importance of going back to previous conditions as means of resilience, but that those conditions need to be followed by actions leading to regaining the water service. Also, that same interviewee highlighted the importance of the speed by which one can recover: “Resilience in general terms, I think it is the ability to get up when you fall, how fast you get up” (CommunityAqueduct_12). A different participant underscored the importance of surpassing obstacles in resilience: “Resilience, basically the ability to overcome obstacles, and move forward by 100% or almost 100%” (CommunityAqueduct_ 1).

By defining resilience as an outcome, programs and stakeholders can fall prey to employing command and control approaches to risk and disaster plans, which can preserve communities’ status quo (Manyena, 2006). Various stakeholders mentioned the implications of resilience related to preserving the status quo of a community: “Well, when you get people used to living like this [under precarious conditions], well, resilience is like breakfast. They get used to living in a condition of alertness, literally and of survival, or subsistence” (NGO_13).

Similarly, another participant talked about how resilience has been used in Puerto Rico to force communities to take governments responsibilities:

> "*What happens is that the term resilience…and I have to roll my eyes; I know what they are talking about, but I personally get picky because I think that resilience has been misused to put additional weight on the communities of what is a state responsibility. When you talk to me about resilience, which is the term, I know what it is, but how I feel about it is different".*(NGO_21)

Even when this was not the dominant discourse about resilience, it is critical to highlight it because it questions those understandings of resilience employed on the island purposely or not to maintain the status quo. Under that same logic, another interviewee highlighted that if the meaning of resilience is to maintain unjust conditions, then he is not in agreement with that definition:

> "*I don't like the word. If the meaning is that you have to get used to bad things, then I do not support it. If the definition of resilience is your ability to cope with bad circumstances at a given time, then that's fine. But if the meaning of resilience is that I have to live with these [unjust] conditions, then no, I don't like the word. I don't like the word because if the condition is not good for the human being, it has to be addressed".* (EducationInstitution_6)

Resilience as an outcome considers that resilience can only be applied to physical infrastructure. For example, the previous argument can be seen in the following quote:

> "[*Resilience] is bouncing back from an interruption quickly, so you know, having policies in place of who's going to go do what, figure out what's wrong and how to fix it, and having a backup system. In a rural water system, it does seem to me that having a tank, maybe most people do have a secondary tank on the roof in case the system goes out, so I think that increases resilience*" (NGO_16).

Even when the quote talks about policies supporting actions leading to resilience, the main point is the importance of infrastructure in building resilience. Here, another NGO argued about the importance of having infrastructure to build resilience: "I think the simpler your system is, the more [resilience]. The more complicated, you have different points of vulnerability, because when you have a single tank, a single well, you have two points of vulnerability"

(TechnicalInstitution_17). This participant is thinking about resilience in terms of infrastructure, which can overlook the inclusion of stakeholders in this process and obscure broader standpoints that can capture interrelations and linkages between humans and the built environment. Participants that saw resilience as an outcome used the term 'cope,' 'bounce back,' 'withstand,' or absorb negative impacts (Manyena, 2006). These understandings reflect a reactive stance on resilience. These definitions might work to describe materials (e.g., iron, wood, mineral, among others) capacities to withstand temperature and regain their original state, but when it comes to people, the same might not apply. The 'outcome' framework quickly focuses on the speed of recovery from a shock or impact regarding disaster resilience. Under this understanding, people and communities are considered flexible, enduring, and unchanged from the impact of stress and shocks (Vickers and Kouzmin, 2001: Manyena, 2006).

Resilience as Process

Seeing resilience as a process recognizes the human role in disasters, acting, having plans, building the capacity to implement a plan, and sharing information about recovery are critical steps to enable resilience (Manyena, 2006). As such, this resilience understanding recognizes the ability of the individual, groups, and community to deal with extreme weather events (Manyena, 2006). Furthermore, it highlights that people are not passive actors, in which an external force is imposed on them and they 'react' to set events, but instead is a quality that can be achieved. As such, it can highlight the community's capacity to empower themselves to be able to organize to face adversity. Finally, through this understanding, we can observe various degrees of being resilient, especially thinking about how we can be resilient through time; the fact that a community perceives itself to be currently resilient does not mean that it will remain so in the future.

Many community aqueducts highlighted resilience as a process in the long run, including their action to respond to a disaster: "For me, resilience has to do with the actions that I take and that in the long run they payout, making me able to respond for the next time more appropriately. Give people the tools so they can also solve more in the long term" (NGO_3). This NGO highlights a critical component of the definition: the importance of providing people resources so they can face those events. In tandem, resources also help community members create a mental state in which they are more likely to take control of the action in the face of disaster. We see that argument in the following quote:

> "*...For me, the point of recovery is that it has to be done quickly. It is good that you said recovery because I don't like [the word] relief very much because [recovery implies that] you first appease the pain and then one start to recover, because [under disaster conditions] when you get hit, recovery has to come quickly. If we continue to give these people a cistern or a filter, they will not get out of the mentality that they don't have water in the house and don't have electricity. So, we are going to at least give him water in the house so that we can change their that they can't move forward or recover. If we reestablish the water grid, communities can say we already have water; we can do this, I can wash, I can [do other things*]" (TechnicalInstitution_14).

As mentioned above, understanding resilience as a process enables communities to confront disasters and extreme weather events. This quote also emphasizes the importance of the psychological component of recovery and resilience; if communities impacted by disaster can reestablish their drinking water services, they are more likely to engage in other actions leading to recovery. Other community aqueduct mentioned the importance of creating plans in looking at resilience as a process:

> "*I always see the term resilience within the sustainability of a project. For me to make a sustainable project within my operation, there has to be a plan that establishes what I am supposed to do in extreme conditions, whether a hurricane or an earthquake. So, I want to see resilience within the planning scope of an organization, to be able to look at that community enterprise and say, "In Puerto Rico, there are hurricanes every ten years, and we know how to prepare to face them*." (NGO_21)

Community aqueducts, non-governmental organizations, and one former government official refer to resilience as a process. Resilience as a process supports the idea that communities can come together to overcome difficulties. Many interviewees use words such as empowerment and ownership to refer to their system.

> "*That's why I tell you; our people have a lot of desire, awareness that they own the system, that this is theirs. For this reason, sometimes they fight so much, even though they could be connected to the main water system they do not want to join, because of that sense of belonging of their aqueducts*" (GovernmentInstitution_7).

This participant underscores the importance of ownership in mobilizing and caring for the system. Similarly, other participants emphasize the importance of ownership in providing water for their communities: "…Yes [we are resilient], because for that very reason, because the community has control of its own water, we know our needs, so we can solve our problems" (CommunityAqueduct_1). Other contributors talked about the importance of empowerment as a whole even when they disagree with the word resilient: "Yes, you have to be resilient, although the word is worn-out and has been overused, communities need to learn how to be empowered, they need a lot of empowerments" (CommunityAqueduct_13).

Interviewees also saw the degrees of resilience in a community as a defining characteristic. Resilience as a process considers various degrees of resilience within the same communities (e.g., some residents are more resilient than others). For example, some community aqueducts emphasize the importance of engaging in activities that would allow them to be resilient to future catastrophes. However, the fact that they are resilient now does not mean they will be in the future. The following quote is an example of this argument:

> "*What I mean is that the knowledge and commitment to maintain these systems, the knowledge of how community systems are managed, the technical issue that had been passed from generation to generation…and suddenly there is going to be a time in which the old people who are running these systems are not going to have someone to delegate*

> *these systems to, and there will be no one to learned how to maintain them*" (GovernementInstitution_20).

There is a growing concern within community aqueducts that because most of the people running these systems are old and there is no generational replacement, these systems can disappear eventually. Another aspect that can affect the degrees of resilience is how resilient a community is prior to an event. Community aqueducts with strong community cohesion[26] can facilitate processes leading to resilient outcomes (Arbon et al., 2019). This cohesion can occur if any of the following occurs; personnel or aqueduct operators are very involved in the community or when the community aqueduct is the official representative of the community to address other non-water issues. The resilient capacity of an aqueduct can be impacted by its community members:

> "*A community can make an aqueduct resilient. Our aqueduct is underway [to be resilient]; some are more than others, and others are not. Going back to my previous point, there are many steps to make an aqueduct resilient, first is that you have to make their community resilient*" (NGO_21).

In tandem with the previous argument, community aqueduct mentioned how internal characteristics could also affect how resilient a community can be:

> "*…There are variables that the communities do not always control. That ownership depends on the will of a person, yes. And it depends on the will, conscience, empathy, solidarity, knowledge, and civility. In some communities, it can happen. Communities can be subject to these ups and downs*" (CommunityAqueduct_8).

No Resilience

In this discussion, I have highlighted how resilience can operate as an outcome or a process. Still, some stakeholder answerers did not fit either framework. These understandings highlighted that not all stakeholders understood the concept of resilience. It also underscores that some participants used a different framing. As a result, some participants underscored that one of

[26] What must happen in all communities to enable different groups of people to act to gether to accomplish a desired objective

the difficulties of using resilience is that it does not necessarily have a clear definition: "Although I've heard it a lot, I haven't necessarily seen the definition. Sometimes words have a problem, one thing is the definition of a word, to say something, in the RAE (Spanish Royal Academy) and another thing is how people use it" (TechnicalInstitution_17). The same was true for some community aqueducts that did not understand the concept: "I don't understand the word" (CommunityAqueduct_11). In general, many stakeholders had problems defining resilience, suggesting we should not take resilience as a phase value. The previous argument also helps make sense of the challenges of understanding resilience.

However, even other participants who were unsure of the concept could link it to their survival: "You know...resilience, uhm…supposed to mean…to survive more or less, no? That's what I understood so far. It is what I have been made to believe. And for now, we have been able to survive, except when it came to our power source, we still rely on fossil fuels" (CommunityAqueduct_5). Similarly, other interviewees define it as means of survival. One interviewee mentioned: "Resilience is how can they survive and come back from the next hurricane, to be honest, that's the threat they will face " (NGO_15). Under disaster conditions, what it means for communities' aqueducts to continue being resilient is being able to survive future storms and extreme events. Another participant underscores their capacity to act and survive no matter what:

> "*They are not resilient by design; they are resilient by nature because you have to survive; there is no other choice. There are indeed cases where you see many leakages and broken pipes in their systems, but there are many cases where they simply think that the water has to get to people's houses one-way or the other. For me, that is resilience, no matter what is happing around you, in the face of the situation, you have to be able to move and do it*" (TechnicalOrganization_2)

Even when resilience was framed as the means for survival and allowed many community aqueducts to 'overcome' adversity, it has dramatically affected these small water systems (e.g.,

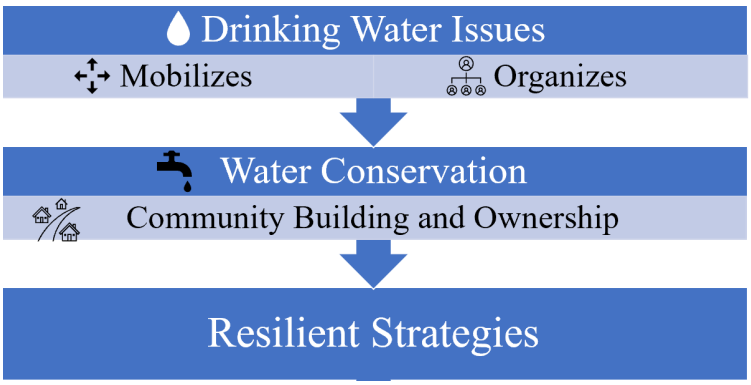
personal sacrifices, mental health problems, financial instability, etc.). Those who were able to mobilize did it by reconfiguring the community. These reconfigurations took different forms; for some, they meant more community participation, while for others, it meant moving out of the community. Leaving after a disaster may not be a possibility for everyone. For those who could not leave, they underscore the importance of mutual aid community systems in their survival:

> *"It is vital that you keep in mind that the economic capacity of the families that belong to these systems is very tied to the fact that they are surviving with mutual aid systems. Not all of these systems are prosperous, except for very few; ASOCAGUAS is perhaps the exception, but many of these families are forced to keep these systems running precisely because they do not have the resources to leave, but they are exhausted"* (GovernmentAgency_20; NGO_21).

Enabling Resilience

In the previous section, I discussed how resilience looks for different stakeholders engaging with community aqueducts. Still, that discussion was limited to identifying important resilient characteristics and the implications of understanding resilience differently. Yet, we do not know the mechanism that enables these understandings. Therefore, this section focuses on that discussion. I argue that issues related to drinking water, e.g., lack of access or a perceived threat, force communities to mobilize and organize and, as a result, enable water conservation strategies and foster community building and ownership. Consequently, these water conservation actions and community-building spaces have allowed community aqueducts to create and implement resilient strategies to face catastrophes. See figure 5 below, which showcases how community aqueducts can enable resilience.

Figure 5. Small Water Systems Process for Resilience



Issues related to drinking water creates the conditions in which a communities mobilize and/or organize around those issues

This mobilization and organization fosters water conservation strategies and provides a space for community building and ownership

Water conservation strategies and community building, and ownership processes resulted in resilient strategies

Community aqueduct highlighted how issues of water, whether lack of and the perceived threat of the main water utility taking over their systems trigger their action:

> "*Perhaps our motivation when we started, when we decided to be part of the board, is because they were talking about the fact that the previous board had negotiations with the previous mayor to hand over our aqueduct system without consulting our people*" (Community Aqueduct_14)

This perceived threat came from the possibility that collective organizations and or the main water utility (PRASA) would take ownership of the system:

> "*I went to a community meeting where they told us that the cooperative will cease to exist and that they are going to transfer back the aqueduct operation to each neighborhood. Because in Patillas each neighborhood had its own community aqueduct; there were a lot, I think there were about 8 or 10 aqueducts, so I felt I needed to get involved* "(CommunityAqueduct_1)

A similar argument was raised by community members who decided to become involved with the community aqueduct. However, participants mentioned they were not engaging with it until a water issue triggered their action:

> "*As I told you before, I moved here five years ago—there was a problem with the water, and instead of being part of the problem, I decided to come forward and be part of the solution*" (CommunityAqueduct_13)

Besides water issues, interviewees highlighted the event of hurricane Maria as something that also made them want to get involved and helped the community:

> "*During Hurricane Maria, well, we had trees that fell and took out pipes and infrastructure, and other things. We had to identify everything that was damaged basically; between the neighbors and the operator, we were able to fix it very quickly*" (CommunityAquedct_1; CommunityAqueduct_7, Aqueduct 5)

The previous two quotes highlighted how communities needed an external event to trigger that action. Another participant made a similar argument about how crisis can motivate them to act: "In times of crisis, the neighborhood does help. In times of stability, they always sit down and not do much" (CommunityAqueduct_14). In short, water issues mobilize and promote the interest of the community.

Another way participation can be triggered on community members is by a sense of community responsibility and identity. From a young age, some participants saw their community aqueduct as something that was part of the community and something they had to defend: "Our people see this aqueduct as our heritage because it was our grandparents, great-grandparents, who built it, and we want to defend it." (CommunityAqueduct_14). From mobilizing and organizing around, water issues came up with strategies for water conservation and building community. Regarding water conservation, some interviewees underscored how it was a product of how hard it was to access drinking water:

> *"After connecting back to the community aqueduct and having water, the community saw how important it was and how difficult it was to obtain it. We were very aware of conserving water."* (CommunityAqueduct_1, CommunityAqueduct_5, and CommunityAqueduct_11)

Similarly, other interviewees underscore how when people do not have water, they become more conscious of using it: "There is a little more awareness [after the Hurricane]. Because this, the absence of water can scar you" (CommunityAqueduct_8; CommunityAqueduct_9). Some of these community water conservation strategies' have been turned into formal programs,

including educational campaigns. However, most water conservation strategies focused on telling residents to reduce their water use and installing water meters.

By engaging and working with the non-PRASA systems, collaborators created spaces for community building, which supported the importance of the system's ownership. The systems ownership was critical for community aqueducts to obtain access to drinking water in the shortest amount of time possible, especially in the aftermath of Hurricane Maria:

> "*The fact that we could control when and how we are going to receive the water, I believe that gave us the control and knowledge, breaking away from the dependency on someone else, we did not have to wait for someone from the main water utility to connect the water system back. The community was super prepared and mobilized quickly*" (CommunityAqueduct_1, TehcnicalOrganization_1)

This argument also highlights how critical the system's ownership was in being able to mobilize quickly to address any issue. Ownership of the community aqueduct was connected to the decision-making power within the aqueduct:

> "*Look, you have to have a linkage of sorts [with the aqueduct]; you need to be able to identify and look at your alternatives to be able to work with any problem on the aqueduct. If you do not have this, and you do not have the power to make those decisions, you cannot deal with the problems because you need to have the capacity to make decisions; you need to have that strength*" (CommunityAqueduct_9)."

Regarding spaces for fostering community building, the interviewee highlighted how those were created through collaborations in the community aqueduct:

> "*Well, this aqueduct is like glue; thanks to it, other collaborations occur; let us put it like this. Since we are all so dispersed, so far from each other, maybe those collaborations would never happen without the aqueduct. We would never have collaborated to clean up the road. The aqueduct supported us in different ways, well, I don't know, I don't know, maybe it would have happened, but we wouldn't be so close as a community*" (CommunityAqueduct_2, CommunityAqueduct_14)

Spaces to build community are very diverse in the context of community aqueduct. While some participants underscore the importance of collaboration and working together in building community, others emphasize how their community aqueduct was used as a launch point to build

other spaces that are equally important for their community: “The Aqueduct is one of the Projects of this community. However, right now, we provide other services, we also have tutoring center, two community activity centers, a gym, and an emergency center” (CommunityAqueduct_7).

Resilient strategies are those processes in which communities engage to allow them to face future environmental threats. By looking at resilience as a process, we can understand the different steps in Figure 5 and the mechanism that enables resilience. One interviewee underscores the importance of having the systems up to date to face future environmental hazards:

> “*But then, after Maria, we realized we needed to have the systems up to date. If you’re going to use water from the aqueduct, that’s fine, but we need to make sure the system is up to code; we need to be ready for the next drought. With the drought, the water rationing comes, and things get complicated, or if we have a power outage, that complicate things too, specifically because under these problems the pumping systems of the government water grid do not work*” (Aqueduct_2; Aqueduct 5)

In line with the previous quote, other participants highlighted how mobilization was critical in operating community aqueducts. Without this organization and mobilization, aqueduct capacity to be up to date is limited, affecting their future capacity to endure catastrophes. Other participants underscore the role of the community members who built the system, as they provided a pathway for future generations, including knowledge transfer to continue operating the aqueduct:

> “*There was a strong base of old men and women who initially built and took care of the community aqueduct, right? They took their time to organize the community, to give it shape. That is a beautiful story; I would write it if I were a writer. I imagine their work in organizing the community; they gave everything they had in doing so. It would not be possible to have what we have today without them. What we have today is good, so this must be true. How were they able to achieve, what they achieve, one wonders.*” (CommunityAqueduct_12)

A solid organizational base has proven critical for community aqueduct survival in future disasters. Those aqueducts that have passed down their knowledge of the aqueduct from generation to generation continue to survive. Others plan to guarantee their survival by getting the younger generations involved in the aqueduct process.

Finally, the following is perhaps the best quote highlighting when a water issue triggers an action to when resilience is enabled:

> "*We met the next day that we could go out, right? When we were cleaning the roads, we looked at each other and said we didn't have water; what were we going to do? Well, one of the neighbors is a cousin of mine who is already in his mid-50s. He told me, look, I know where the water springs are. He asked me if I knew how to get there? I told him I remembered, but I didn't know that well. He then said that he knew because his father built the aqueduct. So, we started making our way through the forest until we found the natural springs. We identified what we had to do, and everyone wanted to be there; everyone wanted to work. We needed materials and pipes, and it was hard to find them. We had to go all the way to Arecibo to see if they had any. Finally, we ended up in a hardware store by Utuado; everyone pitched in to pay $600 for the pipes. This process had really cool moments. One of the old ladies who could not participate in this physically and who lived far told us, if you bring me some food, I can cook lunch for everyone.[and again, everyone pitched in to get the food]. Now we have water, and we do not depend on anyone*" (CommunityAqueduct_2).

The quote highlights how after Hurricane Maria, a community did not have water, and the whole community mobilized to obtain drinking water. Through this mobilization, they were able to organize to get construction materials. Most community members not only participated in installing the new parts but also built and reconnected social ties in this process. In the end, they were able to rebuild their system, build ownership and cut dependency to external aid.

Conclusion

The discussion of the subjectivity of resilience as a concept is vital and complicated. While different fields may have different understandings of resilience, it is essential to understand these differences and where they originate from to understand how resilience is operationalized under disasters. Understanding how resilience is enabled is critical; we know which elements and factors

are needed to create resilience outcomes. However, literature is limited in showcasing the mechanisms that enable it on the ground. The case of Puerto Rico's independent community aqueduct presents a crucial case in this discussion. We saw that water issues serve as the arena in which mobilization and organization are triggered, but water conservation, community building, and ownership are the mechanisms by which resilience is enabled.

Even when it is complicated to untangle, resilience as an outcome and resilience as a process because they are related, they pose very distinct understandings of 'resilience.' Resilience as an outcome was inclined to be used by institutional stakeholders that focused on the ability to bounce back without questioning if previous conditions were favorable at all for residents. This is particularly relevant in the case of Puerto Rico, as many communities in which community aqueducts operate are poor, with limited government support and aging infrastructure. Participants that used the process framework tended to focus on the collective actions and decision-making process as key to tackling catastrophes. It is essential to highlight that even when resilience as an outcome is focused on peoples' inherent 'capacity' to withstand an external factor, focusing less on the actual process that individuals or communities carry to overcome those events—both institutional actors and community actors used this frame. Even when more community participants employed the process framework, many community participants employed the outcome framework, suggesting more research on the relationship between the two.

Two central theoretical significance can be derived from these two frames. First, if government institutions continue employing an outcome approach without considering breaking and addressing previous social and environmental inequalities in these community aqueducts, they risk forcing them to live under unjust conditions. Second, focusing on the process outcomes has provided a space to think about how we can implement long-term recovery strategies and policies

that address social and environmental inequality root causes.

Even when communities were unsure what resilience meant, some had the resources and network to survive and resist their erasure[27]. Identity plays a crucial role in their resistance to transferring or giving away their aqueduct to PRASA. Many saw the operation of these small water systems as a duty or social obligation they had to carry out. However, in doing so, they can fall under a catch-22 scenario, in which they must keep operating no matter what because they provide their only means of survival. Knowing these aforementioned conditions are critical to approaching with caution when we argue that community aqueducts are resilient; yes, they are resilient, but it is because they have to, not because they want to; their survival is at stake.

After hurricanes Irma and Maria, many islanders saw how fragile the energy grid was on the island. Many interviewees reported that they were out of electricity in the aftermath of the 2017 storm season because the power grid was out for months. As a result, many communities started mobilizing to obtain non-fossil fuel technologies, like solar panels and windmills. These decentralized small-scale energy distribution systems would improve community aqueduct resilience by cutting their dependency on a dilapidated energy grid system. In the eventuality of future power outages and hurricanes, they would continue operating and distributing water, even if the primary power grid is out. Continuous and reliable drinking water is a critical component of any sustainable society, even more under disaster conditions.

Water provided a vital space where community aqueduct could frame their strategies to manage their resilience. Because of the interconnectedness of water with other natural and human systems and the networks it produces, community aqueducts used these networks to foster spaces to build community and strategy building, which ultimately aid them in accessing essential

[27] Hurricane Maria, the earthquake event of 2020 and the COVID-19 pandemic, force many residents to leave their communities, which meant that some aqueduct had no personnel to be operated, forcing them to transfer their systems to PRASA

resources. Finally, future research should focus on more ‘soft’ water paths (Grant et al.,2012: Gleick, 2002). This would address water management issues as they provide an alternative view to a ‘hard’ water path that mainly focuses on centralizing systems as ways to capture and treat the water supply. ‘Soft’ water paths focus on decentralized facilities (like the community aqueducts), policies, and human capital that deliver water services that can match users on their specific scales and needs.

Note

All interview quotes were translated from Spanish by the author

CHAPTER 5: CONCLUSIONS

Overarching Findings

This dissertation investigated how effective disaster resilience needs to incorporate the goals of environmental equity and community empowerment under our current climate change context. My methodology approach shaped my research choices, which also shaped my research findings. My first study revealed the social media role under hurricane Maria, while my second study underscored the role of community aqueducts in accessing critical resources under disaster conditions. Furthermore, my third study looked at how communities on the ground affected by disasters understand resilience. The three empirical chapters' results underscore the importance of social media, governance processes, and community participation in shaping effective disaster resilience. The dissertation also highlights the role of water systems as a vehicle to examine disaster resilience processes.

In the second chapter, I highlighted social media's capacity to build resilience. Social media provided a space where people could relay and access essential information that would not otherwise reach communities in need. These messages included information about where one could donate to help Puerto Rico or about avoiding potential risks. Even though my sample of people residing in Puerto Rico for the social media analysis at the time of the Hurricane was small, they reported how Twitter was critical to accessing vital information pre and post-event. These messages mainly focus on news of the event, discussing sociopolitical and scientific causes, and expressing emotion. The way communities employ these messages to their advantage highlights their potential to help each other during a catastrophe, which can make a difference in the recovery process.

My dissertation emphasizes communities' potential for helping each other through social media or on the ground during disasters. These findings support how social media can provide an

alternative voice on the ground to communities under disaster conditions (Sarrica et al., 2018). Thus, effective disaster resilience must consider diverse forms of resilience to be effective. If we only consider one form of resilience, it can lead to the exclusion of others; this is why we need to consider a further understanding of resilience that includes diverse stakeholders, especially those historically marginalized.

This dissertation also reveals how diverse governance processes were critical to effective disaster resilience. Governance refers to all governing processes that are undertaken by a combination of governments, markets, or networks, whether over a family, tribe, formal or informal organization in our society (Bevir, 2012). The importance of looking at governance as an analytical lens is that it allows researchers to take stock of governing process among other non-state actors such as non-governmental organizations, private companies, individual citizens, and communities (Bakker & Morinville, 2013; Larson & Weik, 2012; Llano-Arias, 2015). It also opens the possibility to look at a diverse array of stakeholders that have the capacity to affect governance outcomes (Howard et al., 2017), a difference that has the potential to illustrate why or how some water governance systems are more resilient than others in the face of extreme events. In my fourth chapter, I illustrated how governance processes among a variety of stakeholders impact the capacity of Puerto Rico's small water systems. Governance of water systems is referred to as water governance. A critical component of water governance is that the systems and resources associated with it must be sustainable, as it will ensure access to water for current and future generations. However, this requires the consensus and participation of all stakeholders and their water-related supply—including delivery and uses—to ensure a sufficient and equitable level of social and economic welfare without compromising the long-term viability and integrity of water systems (Hall & Rogers, 2003; Langsdale et al., 2009; Reed &Kasprzyk ,

2009). Still, this is not straightforward, as inequalities and systems often hinder such processes and sustainability efforts.

In chapter three, I found that how residents operate and govern their water systems impacted disaster resilience, which I operationalized through their recovery. Collective decision-making was significant for small water systems recovery. This finding is aligned with theories highlighting the potential of collective decision-making in disaster resilience (Zobel, 2011; Gil-Rivas & Kilmer, 2016; Kapucu, 2013). Still, this finding should be approached with caution since some participants highlighted that in some instances, collective decision-making led to a slowdown in the process towards action during a disaster. In chapter two, I also discussed how a community aqueduct could be considered a social movement that operates through different networks, more specifically, how their collective action can facilitate resources by engaging politically across those networks. Not only do they operate via different networks, and relate to these networks differently, but those networks are critical for the operation and effective functioning. I equally argued in that chapter about the importance of their potential for resource mobilization and the recovery process of community aqueducts. The more networks (neighbors, public officials, friends, family) small water systems participated, the shorter the recovery time.

I highlight in chapter four that networks were crucial for accessing essential services, aid, and food. Many factors can impact the strength of a network. This chapter also argued that how community empowerment and spaces to build participation were critical for networks, making them vital for disaster resilience. Solidarity was essential within these networks. Roque et al. (2020) research highlight how community members express their solidarity with one another. One of Roque et al. (2020) interviewees states that "[After hurricane Maria it] was a lot, a long critical period, but those women were there giving that solidarity hug, that strength and that

energy that was necessary for the early recovery of this community." Solidarity was translated differently depending on the case and situation. Some people helped in kind (time, work, among others), provided goods, or put in extra hours at their jobs. While my work mainly focuses on the case of community aqueduct, other support networks that impacted the overall recovery process of communities were soup kitchens and mutual aid centers. In one of my interviews, Juan[28] explained that these soup kitchens became hubs for food, ice, water, electricity, and other resources in the aftermath of Hurricane Irma and Maria.

Political Ecology is an approach that aims to counter the overemphasis on technology and socio-technical problem definition by highlighting the importance of natural systems and their limits. In addition, political ecology allows us to observe how different actors and stakeholders interact within these levels and how one can affect the other. For example, how decision makers have traditionally created policies that favor development and economic efficiency over principles such as fairness and environmental protection (Feldman, 1995). A political ecology approach to resilience allows us to look at the tradeoffs and relationships between the meso-level of resilience and the macro-level. Within the political ecology spectrum, I differenciate resource access across societies and individuals and how those variations and accessing resources affect their material conditions (Turner, 2014; Swyngedouw et al., 2002). This approach is even more relevant when we look at water issues occurring on community aqueducts and affected communities in Puerto Rico. This lens can illuminate how the state's socio-technical perspective on water infrastructure interacts with informal water infrastructure and how it can prioritize one over the other. By prioritizing socio-technical approaches or what Sofoulis (2005)

[28] The interviewee's name was changed for privacy.

calls Big Water[29], the state can leave out community-based resilient strategies to ameliorate water issues, disfranchising communities' approaches that have proven critical in the face of disasters. The political ecology approach I employed draws upon ethnographic research. By following communities' aqueducts day to day activities, and interactions on the ground, I was able to witness firsthand how divergent resilience perspectives emerge—Including its relationships with water uses.

Regarding water governance, this dissertation discusses how community aqueducts performance is an example of failed governance and, at the same time, what Ostrom (1961) calls polycentric governance. Puerto Rico's failure to manage its water security is a complicated issue. It results from several factors, including lack of political power, mismanagement, dilapidated infrastructure, cascading disasters, and clientelism. The state has overlooked its responsibility to provide water to rural communities, and its support for the community's aqueduct has been limited at best. Past and current disasters have demonstrated the state's lack of capacity to serve water to all its inhabitants, even when they argue that the central water systems provide water to 97[30]% of their citizens (Preston et al., 2020). Even under these dire conditions, and limited political power, there are areas of opportunities to reform current policies that would lay the foundations for implementing just and equitable strategies and actions leading to resilience. If the state cannot provide water to all its citizens, then at the minimum should support those small water systems that can do so. There are currently three policies under consideration in the local state legislature that would improve aqueduct operation. These policies recognize that community aqueduct organizations provide critical water and social services to their

[29] Big water is associated with socio-technical water systems in which often domestic users get blamed for water practices the system encourages and services trough years (Sofoulis, 2005)
[30] Do to change in demographic patters, and recent disaster, the actual coverage number might be lower

communities and should not be considered as any other water utility. One of these policies would include them in the water task force, where local state agencies and stakeholders discuss water management strategies. If approved, the third policy would grant them amnesty from overdue fees for their registration.

Community aqueduct governance is also an example of what Ostrom (1961) calls polycentric governance and how these systems can bring greater resilience. Polycentric governance is a form of governance with multiple decision-making centers (Carlisle & Gruby, 2019). It relies on sometimes improvising collaboration based on negotiated rules of exchanges instead of a hierarchical governance institution. For example, community aqueducts can negotiate specific taxes or amnesties if they deem it to their advantage. This governance system has notable advantages, highly adaptive capacity, and risk mitigation. In my dissertation, community aqueducts demonstrated that their decision-making approaches have, in some instances, brought them together, facilitating the design and implementation of resilient actions.

In conclusion, social media use, community empowerment, and water governance are vital for effective disaster resilience. Under our current climate change conditions, these elements are vital not only for communities to phase catastrophes but also must be included when we think more broadly about implementing recovery actions. For example, one of the critiques of disaster recovery in Puerto Rico is that the government may not have the capacity or time for substantial analysis and public debate about balancing short- and long-term societal needs (Finucane et al., 2020). Inadequate attention to this challenge may result in a deepening of the inequities that increase vulnerability to disaster impacts (Finucane et al., 2020. p1), which is why they need the combination of social media, water governance, and community empowerment for effective disaster resilience. These elements are essential, especially for

communities with limited political power and experiencing social and environmentally unjust conditions, such as the community aqueducts.

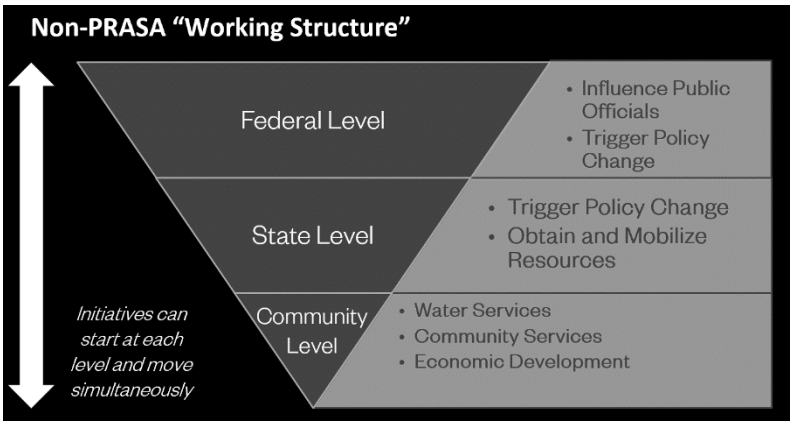
It is also worth noting that this dissertation reveals the importance of employing mixed methods to measure such a complex phenomenon as resilience, including how other variables are interrelated. As I argue in the introduction chapter of this dissertation, pairing a content analysis of Twitter, survey responses, interviews, and an ethnographic approach to residents' that worked in the community aqueduct provides a richer understanding of the dynamics at play when looking at effective resilience. These approaches are critical to identifying broad underlying factors that affect communities under disasters, such as community aqueducts. They bring critical insight to understand the mechanisms at play when people on the island define resilience. The fact that I showcase three distinct factors (social media, water governance, and community empowerment) that impact how we think about resilience underscores the importance of having a multi-perspective when analyzing its impact on underrepresented communities. On one hand, the Twitter analysis showcases the importance of accessing other non-traditional disaster communication outlets, such as social media, which aids impacted communities in finding and relaying important information vital for their recovery and overall resilience. On the other hand, the survey demonstrated how collective mobilization and networks were critical for community aqueduct recovery. Finally, the ethnographic approach suggested that a new language is needed to align with the ways resilience strategies are implemented on the ground. This last argument is critical in designing policies attuned to the social realities and contexts of those communities' policies intend to help.

Theoretical Significance

This dissertation shows that in order to understand resilience to disasters in developing societies, we must understand the phenomenology of resilience and help theses societies fortify themselves again environmental hazards. Even when different fields have divergent understandings of resilience, most of these fields focus on formal 'knowledge' and professionals to define it. In the resilience literature, just a few definitions focus on communities' and societies' perspectives of understanding resilience (Manyena et al., 2019; Berkes & Ross, 2012). This dissertation shows that taking their understandings into account is critical to designing solutions that can address underlying inequalities that trigger disasters within disasters and finding common ground of what it means to be resilient. Without this common ground, we risk creating solutions that do not address concerns and problems related to how resilience is understood from 'below' or from the ground. Furthermore, this finding is aligned with Manyena et al.. (2019) and other authors (Berkes & Ross, 2012; Kapucu et al., 2013) that emphasize the importance of bringing underrepresented communities into the decision-making process aiming to build resilience. If governance simply means the capacity to recover from a disaster without changing the organizational forms that led to the disaster's worsening, then governance is not addressing the problem. For example, the absence of essential participation by underrepresented groups and the exclusion of the voices of people of color and women; if that does not change, then we still have a resilience problem, and it is a governance problem, but the two need to be better integrated. Only by incorporating them can they build political power, which is critical to help them address their environmental and social issues. For instance, not only have small water systems residents decided to get involved in the operation of their community aqueduct, but at

the state level, they are crafting and designing policies. Figure 6 presents how community aqueducts aim to trigger change at different scales.

Figure 6: Non-PRASA Working Structure



The above structure is critical to understanding how communities can access and put resources into operation and trigger change to impact their resilience. Interviewees highlight how they can operate at three levels, community, state, and federal. At the Community level, they provide water services and other social services, like helping the elderly, tutoring services, and sometimes providing paid work for the community. At the state level, they have the potential to trigger policy as well as access resources, as I showed in Chapter two. At the federal level, they can influence public officials and trigger policy change. Additionally, they can operate at different levels collectively or individually. Collectively, they can participate under regional or island-wide organizations such as OSAN or Fundación Comunitaria de Puerto Rico. Also, their initiatives can start at each level and move simultaneously.

The non-PRASA "working structure" extends from the literature that puts in conversation ecology and social-political literature (Boggs, 2021; Rademacher, 2015), which describes the potential of social and political movements to impact environmental processes and systems. Even when Buggs (2021) and others argued (Giddens, 2009; Ribot, 2006) that change is only

possible by working within current structures in the democratic systems, community aqueducts demonstrated that they could work within formal democratic structures but also outside of them. They can trigger change by working with informal structures when working within the formal democratic system has proven futile. For example, island-wide non-PRASA organizations were working at the Federal level on a concession for a water tax—but ultimately, the overseeing fiscal control overturned the decision, so now they are working with states representative to submit a new policy[31]. An example regarding informality occurs when aqueducts decide purposedly not to register their water intake or not comply with water regulations to avoid future expenses.

Chapter three demonstrated that even when community aqueduct operators may choose a resilience definition (outcome or process), many of them do not even understand or define what it means to be resilient. For people on the ground, resilience meant survival or even resistance. For many community aqueducts, the discussion of what it means to be resilient has been driven by parties that do not necessarily have their interest at hand. They recognize, especially those community aqueducts working in regional and island-wide efforts, that when policies are designed without them and without considering their social context, they become futile. These efforts become pointless, like many policies that the local house senate has approved but have never been implemented.

Interviews revealed that the framework of resilience was typically used by institutions (e.g., government, NGOs, academia). Even when small water systems recognize their resilience capacity, they emphasize its temporal characteristic, an essential element of resilience. They mentioned that even if the aqueduct was resilient (physically and organizationally) or their

[31] Update. This new policy was sign by Puerto Rico's governor and it would gran an financial amnesty to community aqueducts. This would foster community aqueduct path to compliance with the Clean Water Act

residents, that did not imply the community they serve was resilient. They further stress that if governments and institutions wanted to make them resilient, they needed to talk about resilient systems. Considering all the parts of the ecosystems[32] in which the community aqueducts operate could make them genuinely resilient. Consequently, these temporal resilience findings build on previous literature (Frazier et al., 2013) that underscores this characteristic's importance in applying climate change adaptation strategies. It recognizes that if strategies and policies aim to build resilience, they must consider continuous actions rather than a one-time thing.

Understanding tradeoffs between food, water, and energy production is critical for effective disaster resilience. It is also vital understanding that these elements form an intertwined neatwork; each of them dependent in some respect on the other two. I pointed out how the energy sector relates to community aqueducts in chapters two and three. Most community aqueducts are operated through pressure bombs, typically powered by electricity or gasoline generators. Thus, having a continuous and reliable power source is critical for their operation. Even when some aqueducts are run with solar energy, they remain connected to the primary power grid. However, those aqueducts that have been able to disconnect from the main power grid by using solar energy are better prepared to face future extreme weather events by addressing their energy dependency on the island's dilapidated energy grid. Puerto Rico's energy grid is currently in a very fragile state causing rolling blackouts weekly. However, it is essential to consider that while community aqueducts run only by solar energy are resilient, so do systems that work with gravity. While aqueducts operated by gravity typically do worst in terms of their organizational, physical infrastructure, and water quality, they became, in some instances, the only spaces where drinking water could be accessed. Still, many local and federal government

[32] In this context the ecosystem in which community aqueduct operates includes, the natural environment, residents, community, built environment, organizations, policies

officials see this low technology system as outdated and have argued that it should be eliminated. As a result, the government has made funds available to 'modernize' those that operate through gravity. Unfortunately, this 'modernization' has pressure previously run aqueduct through gravity to build a well, making them energy-dependent as most pressure bomb systems operated by electricity. In some instances, this change has made some aqueducts that operated previously through gravity dependent on fossil fuels, even when they now have a better water quality.

While the space in which community aqueducts operate is unique, their experience can illuminate ideas that address environmental problems to other communities and social movements[33] under similar conditions. First, their collective organization and resource mobilization has proven supreme, even under disaster conditions. Second, the dissertation adds to the literature on water collectives (Vos et al., 2020) and their importance in understanding local knowledge and the decision-making process that can shape how drinking water is accessed, especially under disaster conditions. Third, it builds on how the social movement literature (McCarthy & Zald, 1977; Edwards & McCarthy, 2004) understands how resources can be accessed under disaster conditions.

Study three revealed how the lack of water had forced these communities and residents to spring into action. However, this argument should be approached with caution; this does not mean that communities need an external event or crisis for them to be able to mobilize. While some communities were able to recover within months and even years, others could not recover. This expands on literature that calls attention to the different recovery capacities of communities. I found that one critical component that helps some communities to recover by mobilizing where their connection to social networks (Aldrich, 2012; Roque et al., 2020). Rural water systems

[33] See chapter two, where I define community aqueducts as a social movement

provided a space where they could build social ties and foster community, leading them to organize. Their constant struggle to improve their social and environmental conditions has only been possible because they purposely target different scales through different individual and collective actions. Finally, if we aim to have a resilient society, further understandings and new mediums (e.g., social media) are needed; only by engaging through different scales and fields will we be able to live in a constantly changing and evolving world.

Extending Resource Mobilization, Resilience, and Water Governance

Through this dissertation, I employed different theories to analyze how to make resilience effective. To do this, theory must better incorporate environmental equity and community empowerment. I define effective resilience as an approach that considers equity, community empowerment, and participation as means to improve a community's livelihood in the face of current and future disasters. I mobilize disaster communication, resource mobilization, water governance, and resilience theories to answer my overarching research question[34]. Each of these theories captures different components of what effective resilience is. This section focuses on what each of the theories I employ tells us about effective resilience, including a discussion on their limitations, and how to improve resilience theories.

I used disaster communication in the second chapter to discuss how people used Twitter under Hurricane Maria. Data obtained underscore how users were very interested in seeking information about the socio-political causes of the events. This finding is critical because it underscores that recovery efforts are linked to socio-political causes, not only to the storm's intensity. Results from the Twitter analysis also revealed that users were sharing emotions; many

[34] How collective mobilization serves as a vehicle to manage hazards and access vital resources mainly when communities have limited resources and political power?

of the messages included people living outside the U.S looking for their families, including words of hope. Sharing emotions was an important finding since there is literature that points out how it can serve as a cathartic exercise to manage the event (Mittal et al., 2021). This finding reveals that recovery efforts extend outside the impacted country's borders. One limitation of using social media to find out people's perceptions and behavior under an event is that most users are more educated and affluent, creating a gap with other sectors of society. Still, Facebook and Twitter are not any different from other communication outlets by which technology, power, and privilege can be exercised. For example, some literature examines (Baron, 2006; Moeller, 2006; Sood et al., 1987) news media bias and how this bias can influence political views. Even when Facebook and Twitter can reach millions, it is still limited in terms of whom they can reach. However, a new study suggests Twitter's potential for reaching minority users, especially since they are more likely to believe in government outreach (Brown et al.,2014).This finding means that we need to understand these biases when we analyze social media and that further research is needed to understand the effect of the social media gap and how it can be reduced.

Resource mobilization theory was used as an anchor to explain how communities in Puerto Rico could access and put in motion those efforts to recover from disasters. With resource mobilization, I was able to dissect the different steps that the community aqueduct underwent that allowed them to recover. Most notable findings from chapter three revealed that networks (a key component of resource mobilization) were critical for a faster recovery time. Collective mobilization is critical for underrepresented groups and societies with limited political power (e.g., neo-colony). At the same time, some interviewees revealed how critical networks were for their survival (Aldrich, 2012; Roque et.,2020); others pointed out the importance of strengthening their networks for future events—significantly strengthening those ties that can link communities with

government representatives and/or nongovernmental organizations. While resource mobilization was vital in understanding how people can find and put in motion essential resources for recovery, one critique is that collective and social movement growth can be attributed to social stress (Kerbo, 1982), leaving out historical context, which in the case of Puerto Rico is vital.

Diverse scholars refer to water governance as a spectrum (from normative to critical) that favors different governance systems (Pahl-Wostl, 2015; Jímenez et al., 2020; Varady et al., 2009). Normative water governance approaches tend to foster monocentric water systems, while critical approaches prefer polycentric water governance systems (Egas et al., 2009). Furthermore, while traditional approaches to water governance emphasize efficiency and productivity driven by an engineering approach, more critical water governance approaches show that we need to include diverse practices and stakeholders in the decision-making process, not only state actions and actors. Even when water governance can be conceived as a spectrum, its evolution reflects the general trends of shifting from command and control as the guiding principle toward more market-based and, in recent years, more participatory approaches (Pahl-Wostl, 2015.p11). This evolution can be observed in the case of Puerto Rico community aqueducts, where the local government continues to push for a failed command and control approach to water governance while most affected communities by weather events, recognize that effective resilience can only be achieved by having an inclusive and just approach of water governance that incorporates community knowledge and decision-making. In sum, water governance theories provided the setting to observe how water systems are able to enable resilience strategies.

Water governance allows us to identify the different systems that affect water operations under disaster conditions in Puerto Rico. In chapter three, I discuss how collective decision-making vs. single decision-making affected community aqueduct recovery capacity. These findings

warrant that even when water systems are polycentric, it does not automatically imply that their decision-making is horizontal. The previous finding is even more critical to analyze under disaster conditions. This finding brings to attention that even when a collective decision poses benefits, under disaster conditions, when quick actions are needed, a collective decision may not be the best approach as it can cause delays in aid. The previous argument invites us to reflect that different types of decision-making can work better in different contexts and situations. It is important to note that water governance is a spectrum, and as such, there is criticism on both ends of the spectrum. More normative approaches focus on techno-scientific knowledge to analyze, while more critical approaches pay attention to other forms of creating local knowledge and governance (Jacobs et al., 2016: Lukasiewicz et al., 2013). It is important to note that these other forms of creating knowledge and decision-making depend on the degree of citizen engagement and participation. In the case of Puerto Rico, it is vital to understand both because they interact with each other and ultimately affect how it is operationalized, having implications for the Puerto Rico recovery process.

I acknowledge that resilience is defined in different ways depending on the spatial level of analysis. Each level (micro, meso, macro) is vital to understanding resilience in Puerto Rico's context. In the second chapter, I used resilience as the degree of information individuals are able to access on the social media platform. This individual level of resilience is critical to look at, especially when social media is the only media outlet by which people can access information during a disaster. In chapter three, I used a definition of resilience based on theory and observations to look at the community level and how people can recover depending on different variables, including resource mobilization. By operationalizing resilience as the degree of recovery, I highlighted the impact of resource mobilization and social networks on resilience. Lastly, chapter

four employs a more inductive definition of resilience, allowing for definitions of resilience to emerge. This approach was vital because I was looking to measure how communities on the ground understand resilience, which our data reveal is very different from other stakeholders' understandings at a macro level. Most importantly, how each spatial scale can prioritize different types of knowledge, or why some scales focus more on community empowerment (mezzo level of resilience) while others focus more on technocratic approaches. This difference also has implications for how policies leading to resilience are created. Stakeholders looking at resilience at the macro level tend to focus more on understanding resilience as a fixed variable with specific characteristics that can increase or hinder it. In contrast, community members tend to be more inclusive by considering just recovery actions and processes to achieve resilience.

In sum, my dissertation identified three critical ideas resilient theorists need to do differently. First, it has to do with the way we understand resilience. Even when we employ a specific framework in the spectrum of resilience, it is crucial to consider that there are other definitions. A broad understanding of the concept is critical, as it allows us to analyze and identify possible tradeoffs and limitations that might emerge by employing a specific framework. For example, how a particular framework might prioritize professional knowledge overlooking communities' needs and concerns in fortifying their resilience. This can lead to implementing policies that, even if they appear to support communities, fail because they might have not considered or ignored elements critical to building communities' resilience, like supporting their social ties. Considering the historical legacies of the spaces in which resilience wants to be fortified is critical. This dissertation underscored the importance of environmental equity and community empowerment as means to make resilience effective. A first step in bringing equity to resilience needs to consider environmental injustices as root causes of previous social and environmental

vulnerabilities. There cannot be resilience without addressing these previous unjust conditions; only by doing this can we begin building effective resilience. The last element in the conversations about what resilient theories need to include is the inclusion of water governance in any conversation about resilience. My data revealed that how water systems are governed affects society's degree of resilience by impacting its management. Polycentric water governance systems like the community aqueducts have emerged as vital systems to manage future water stress and disastrous conditions. Still, polycentric governance systems may not be a panacea, as they may not work well in any context. However, their effectiveness under disaster conditions in the global south highlights the importance of considering governance as a mediating factor in the conversation about resilience.

Further Investigations

Gender and Disaster Recovery

Through the data collection process of the dissertation, my empirical findings reveal the importance of the role of women, which is in line with other literature (Sledge and Thomas, 2019;Jorge & López, 2021) in the island's recovery process. Chapter three revealed an inequality problem regarding women who operated community aqueducts. Participation of women negatively affected the resource mobilization capacity of community aqueducts. These results are aligned with scholarship that underscores gender inequality around water management (Bhattarai et al., 2021; Bhattarai et al., 2020; Kim, 2022). More specifically, this scholarship underscores how not only are women overburdened with providing water, but when they collectively organize to address these issues, they continue to be excluded from decision-making processes. In the case of Puerto Rico, gender inequality in the water sector is a combination of cultural aspects, legal, political, and social systems (Smyrilli et al., 2018). These inequalities invite us to

reflect on how we could potentially increase small water system sustainability and future resilience by addressing this gender inequality. Addressing this inequality on the island is critical, as women's participation in community aqueducts is increasing. Additionally, this research brings further insight because WASH and its gendered impacts on disasters are understudied (Smyrilli et al., 2018).

The dissertation did not consider an ecofeminism approach as part of its main theories. However, ecofeminism theory will be vital for any future works as; it offers a framework to understand how women tend to experience inequitable environmental burdens (distributional injustice) and are less likely than men to have control over environmental decisions (procedural injustice) (Mallory, 2013; Clough & Bell , 2016). In general, women are at risk up to three-time more than men during disasters and their aftermaths because of multiple factors (Neumayer & Plümper, 2007; Tekeli-Yeşil et al., 2010). For example, women are 20 percent more likely to live in poverty than men. Women also make up a more significant portion of the elderly, which is also typically one of the groups with the highest mortality rates during disasters (Tekeli-Yeşil et al., 2010). However, while women are disproportionately affected, it does not mean they stay on the sidelines during recovery. After Hurricane María hit Puerto Rico, many women mobilized themselves to access vital resources, creating new organizations and businesses, and autonomously harnessed the knowledge required to participate in the island reconstruction (Borges-Mendez, 2019; Calma, 2018). It was mainly women who continued to cook and deliver meals and organize community activities, especially events for children (Lloréns & Santiago, 2018).

Chapter three showed that women-operated small systems tended to face many challenges to operate them. Recognizing this challenge, one of Bosque Modelos' objectives is to

tackle this inequality. They have developed a few efforts in this direction, including one that trains women to install solar infrastructure in their communities. Data collected for four two reveals that even when there is high women's participation in Puerto Rico's rural communities, they still face many challenges, such as overburden regarding WASH practices (Smyrilli et al., 2018). Furthermore, the literature stresses how their resilience resistance[35] is enacted in the domestic space, challenging masculine and patriarchal notions under disaster conditions (Sou, 2021). These resistant strategies can bring unique insight into how women use their social capital to respond to disaster-related challenges. In her work, Sou (2021) describes how women came together to take an abandoned house to use it as a garden to farm produce when there was a food shortage at the beginning of the aftermath of Hurricane Maria. A gendered analysis would be critical in the future to analyze the role of women in these community aqueducts, especially under disaster conditions.

Colonialism

In chapter four, a political ecology approach was used to introduce and expand the implications of colonial dynamics for disaster resilience. Recent disaster events like Irma and Maria invite examinations of persisting colonial power dynamics in discussions of climate hazards (Moulton & Machado, 2019). The social-ecological approach to resilience brings forward the importance of considering colonial dynamics in looking at resilience. As a result, some scholars have critically called for the need to decolonize resilience in the context of Puerto Rico (Borges-Méndez & Caron, 2019;Jorge & López, 2021). This call argues that not recognizing the colonial dynamics can bring notions of resilience that re-in force communities' unjust status quo. By juxtaposing resilience in a colonial context, we can identify water systems'

[35] Bourbeau and Ryan (2018) in Sou (2021.p 15) propose the notion of "resilient resistance" – a tactic of everyday resistance that relies on qualities of resilience such as getting by and adapting to shocks

collaborative strategies as resilient strategies relevant to their Caribbean context. For example, in the case of small water systems in Puerto Rico, communities and academics have argued that the current test used to measure pathogens in the water is too expensive and that a new method should be validated. Validating new methods would require a new federal policy, which would impose an additional challenge on community aqueducts since Puerto Rican representation in congress is virtually non-existent. However, when applying these unequal policies, they are enforced across the board equally, without making any distinction or concessions to recognize the historic inequalities they build upon, which ultimately affects community aqueduct operation. Not recognizing the island's unique cultural, physical, and geographical conditions highlights that what is at play is a lack of social and just environmental conditions enforced by U.S policies. As a result, most of the community aqueducts' strategies have focused on the local scale.

Other issues related to colonial legacies resurfaced when FEMA denied monetary assistance to people with the "same" physical address on their relief application. It is not that the same people were asking for money twice; the island's material conditions have forced many families into single-family units. Something that FEMA failed to consider. Moreover, The *National Disaster Recovery Framework*, designed by FEMA, whose objective is to create a common platform for communities to build, coordinate and sustain recovery efforts, makes a clear distinction between states, U.S territories, and Indian Reservations to access relief funds. The previous argument underscores how territories and reservations are subjected to different legal clauses to obtain funds (U.S. Department of Homeland Security, 2011), creating a legal transplantation issue. This bureaucratic federal agency in contact with colonial legal pluralities and property ownership arrangements is detached from the social expectation of people on the island, who have been made to believe they can rely on the U.S government.

Another example of U.S policy affecting the environment and overall water quality is PROMESA. Under PROMESA, the local government has been forced to prioritize paying bondholders, affecting funds and services that would otherwise go to the residents' service. As a result, Puerto Rico's government halted fund allocation for two-thirds of the island's hydrological stations. Consequently, the USGS could not support these stations with only half the required amount and had to close them in 2016 (Lloréns & Stanchich, 2019). That affected the island government's ability to issue flood warnings and general monitoring of water quality, aquifer levels, and drinking water supplies. Even when the U.S limits Puerto Rico's polity, it is critical to expand research on what are the kind of strategies and policies that can work around or even bypass damaging policies such as PROMESA. The previous argument is critically important because the island's political status will not be solved soon. In the meantime, community aqueducts are still being affected by unequal policies.

A final avenue for future research can be derived from the discussion on resilience-related technology. In chapter four, I discussed the diverse fields that seek to understand the factors that comprise or advance resilience. In that chapter, I briefly discussed how different fields use technology as means to become resilient. Significantly, technology's capacity helps communities adapt to climate change, supporting resilient efforts. In that same section, I caution that while technology is essential, societies cannot become resilient just by relying on technology; we need sound governance policies that accompany communities' collective efficacy actions. Technology has spearheaded water governance approaches that emphasize efficiency and productivity. Unfortunately, water governance approaches that focus on efficiency and productivity tend to prioritize professional knowledge over that from the community (McGregor, 2014). Moreover, this professional knowledge has been used to prioritize "formal"

or institutional vs. “informal” or communal water systems. For instance, engineering approaches to water governance refer to in-house connections to pipes as a “formal” system and standpipes, water trucks, and community aqueducts as an “informal” system (Misra, 2014; Llano-Arias, 2015). Further research is needed that examines the complex normative ways the distinction between the “formal” and “informal” is produced. It must show how this binary system consolidates power and privilege—legitimizing some practices at the expense of others—and perpetuates inequalities (Peloso & Morinville 2014) in Puerto Rico’s water grid.

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