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WATER SHARING AS DISASTER RESPONSE: COPING WITH WATER INSECURITY AFTER HURRICANE MARÍA

Anaís Roque, Amber Wutich, Alexandra Brewis, Melissa Beresford, Hilda Lloréns, Carlos García-Quijano, and Wendy Jepson

In 2017, Hurricane María left more than a third of Puerto Rican households without water services. Cascading failures—including the simultaneous collapse of water, electricity, and transportation sectors—presented serious challenges to the timely restoration of governmental services. In response, families across Puerto Rico adopted self-organized coping strategies to obtain the basic resources they needed, including safe and sufficient water. Drawing on the fast-growing literature on household water sharing, we examine how Puerto Rican families shared water as a response to disaster. Using participant-observation data, interviews, and social network data, we studied water-sharing networks in three municipalities—urban, peri-urban, and rural—in western Puerto Rico in the aftermath of Hurricane María. We found that extensive water sharing (in 85% of households) spontaneously emerged in the wake of disaster, in previously water-secure rural, peri-urban, and urban communities. Households relied primarily on kin and neighbors, and women had more extensive sharing networks than men. Water-sharing arrangements were typically a form of generalized reciprocity, with little expectation of direct payback. We conclude that water-sharing networks are an important—but understudied and underutilized—component of disaster response. Our research indicates that water sharing should be more explicitly planned for and included in disaster preparedness plans. If water sharing is the dominant approach for coping with disaster-induced water insecurity, we argue, it must be at the core of disaster response.

Keywords: water security, social networks, disaster response, social vulnerability, disaster management

When Hurricane María—a category four hurricane—made landfall in Puerto Rico on September 20, 2017, it had maximum sustained winds of 155 miles per hour and 40 inches of rain—becoming the most potent natural hazard to hit the island since Hurricane San Felipe II in 1928 (Fritz, 2018; NOAA, 2017). María destroyed approximately 70,000 homes; more than one-third of households (approximately 1 million Puerto Rican-Americans or United States Latinos)

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were without water services for over nine months, and many families were still without electricity services for more than 18 months following the storm (EPA, 2020; Lloréns & Stanchich, 2019; Sutter & Pascual, 2018). While President Donald Trump approved a Disaster Declaration on September 21, 2017, the initial recovery efforts made by the United States federal government and the Puerto Rican local government were wholly inadequate (Murray, 2019; Willison et al., 2019). The United States Federal Emergency Management Agency (FEMA) sent personnel who did not speak Spanish (the predominant language) and failed to provide residents with the resources and services they needed (Fischbach et al., 2020; Michaud & Kates, 2017; Murray, 2019).

The response of the Puerto Rican Emergency Management Administration (AEMEAD) was also mostly improvisational, with its own national Emergency Operational Plan and Catastrophic Plan mismanaged, in part, due to reliance on a satellite communication system that broke down during the hurricane (Rivera, 2019). At the municipal level, only 24 of the 78 municipalities had an Operational Emergency Plan (OEP) approved before María (Rivera, 2019). A year after María, residents found over 20,000 pallets of undistributed water bottles under the sun in a remote location, exemplifying the failure of governments at the local and national levels to coordinate and manage emergency responses (Weir, 2018). As a result of these failures, Puerto Rican residents were forced to fend for themselves, often relying on stateside diaspora relatives to meet their basic needs for months (Bonilla & LeBrón, 2019; Figueroa & Rolón, 2020; Garriga-López, 2019; Lloréns, 2018; Roque et al., 2021).

In this article, we explore how Puerto Rican residents coped with water insecurity in the aftermath of Hurricane María. Specifically, we examine the role of household water sharing as a form of disaster response, and we include characteristics of the activated social networks that residents relied upon to give and receive water. Most large-scale disasters include disruption or destruction of water services and access. Although water sharing—the transfer of water between households for domestic use—has been shown to be a key mechanism for stabilizing and securing water under conditions of chronic water insecurity (Brewis et al., 2019; Rosinger et al., 2020; Wutich et al., 2018; Wutich et al., 2022), it has yet to be systematically studied as a possible coping response to acute water crises and disasters. Through qualitative analysis of personal networks in three municipalities in western Puerto Rico, we look at (1) how Puerto Ricans experienced water before and after María, (2) the role that water sharing played in their disaster response, and (3) whether residents' experiences have led them to plan for water sharing in the event of future disaster. In current climate change models, future hurricanes and attendant destruction of water supplies are expected for the territory and the region. Knowledge of how water sharing may be mobilized in such situations provides key information for future disaster recovery and response efforts.

Water Sharing as a Response to Water Insecurity

Water insecurity—the lack of adequate, affordable, safe, reliable, and physically accessible water for human well-being (Jepson et al., 2017)—is a chronic stressor for communities around the world, causing detrimental outcomes to biophysical and mental health (Akanda & Johnson, 2018; Bisung & Elliott, 2017; Cooper-Vince et al., 2018; Stevenson et al., 2012; Workman & Ureksoy, 2017; Wutich et al., 2020; Stoler et al., 2019). Growing scholarship on human responses to water insecurity shows that water sharing—the informal exchange of water between households—is one of the most common ways that people cope with water insecurity worldwide (Wutich et al., 2018). A recent global study in 21 sites across 19 low- and middle-income countries found that households borrowed water in every study site; 44% of households borrowed water at least once in the prior month; and failed water systems were strongly associated with household-level water borrowing (Rosinger et al., 2020). In another study across eight sub-Saharan African sites, researchers found that 30-80% of households engaged in inter-household water sharing in response to water shortages and increased water costs (Brewis et al., 2019).

Ethnographic research on water sharing has long illuminated these newly documented global trends (Wutich & Beresford, 2019). For instance, in southwestern Uganda, households engage in water sharing to cope with factors such as inadequate water system maintenance and intermittent drought (Pearson et al., 2015). In Lilongwe, Malawi, low-income families take their empty buckets to more affluent communities to ask for free water (Adams, 2017). Cultural views and beliefs of justice often support water-sharing practices (Beresford, 2020; Harris et al., 2020). For example, in Egypt (Eldidi & Corbera, 2017) and Bolivia (Wutich, 2011), moral beliefs that "water is life" engender water-sharing

practices in water-insecure neighborhoods. Poor water quality and distrust of water providers is another reported reason for water sharing in many communities (Birkenholtz, 2010; Burt & Ray, 2014; Jepson & Brown, 2014).

To date, scholarship on water sharing reveals several cross-cutting patterns: (1) Water sharing most often occurs in response to an acute and immediate need for water (as opposed to sharing water intended for back-up or future supply purposes); (2) water sharing occurs more often among neighbors and others with closely related social ties than among strangers; (3) water sharing is typically a spontaneous occurrence rather than a planned event; and (4) water sharing typically follows norms of generalized (rather than balanced) reciprocity (Brewis et al., 2019; Rosinger et al., 2020; Wutich et al., 2018). Although long-term water-sharing systems are an important feature of some communities (e.g., Schnegg & Linke, 2015; Trawick et al., 2014) and/or may be culturally embedded within other systems of resource exchange (Beresford, 2020), the predominance of these patterns across the water-sharing literature suggest that water sharing may emerge as a self-organized emergency stop-gap measure to cope with chronically experienced water insecurity.

Water Sharing and Social Networks in the Wake of Disaster

While water sharing is widely used as a coping mechanism in contexts of chronic water insecurity, researchers have yet to investigate water sharing at times of acute disaster and crisis. Research in this area is especially important given that climate scientists expect more intense and less predictable weather-related hazards in the coming years (IPCC, 2021). Disaster research points to anecdotal evidence of water challenges (Gheuens et al., 2019; Randolph et al., 2019), and water sharing may be a primary coping strategy to manage disaster-induced water insecurity, especially in the context of government failures. But systematic research is still needed to investigate the conditions under which water sharing can be successfully used as a disaster mitigation strategy.

Disaster researchers have documented the important role of resource sharing more broadly within social networks during post-disaster response and recovery (Bryant et al., 2017; Casagrande et al., 2015; Hossain & Kuti, 2010; Varda et al., 2009). Pre- and post-disaster, people use social networks to gather information related to preparedness, evacuation, sheltering, and related rescue efforts (Eisenman et al., 2009; Hossain & Kuti, 2010; Jones & Faas 2016; Li & Goodchild, 2012). The study of social networks thus allows researchers to identify challenges to proper coordination, decision making, information sharing, resource access, and coordination (Faas & Jones, 2017; Hossain & Kuti, 2010; Varda et al., 2009). Studying social networks also illuminates the structure or patterns of a group and the involvement of members of the group in specific tasks (Faas & Jones, 2017; Heaney & Israel, 2008).

Analyzing formal and informal network relationships assists us in understanding how those patterns either (1) help to prepare or influence positive adaptations to recovery or (2) become a hindrance and inhibit a smoother recovery from disasters or potential risks (Akama et al., 2014; Faas & Jones, 2017). For instance, in examining recovery processes in Louisiana after Hurricane Andrew, Haines and colleagues (2002; 1996) illustrated that survivors with greater social support had better physical health outcomes and lower levels of depression. Similarly, Messias and colleagues (2012) examined existing and emerging social networks among Latinos after Hurricane Katrina and documented the role social networks played in information sharing, decision making, and resource access.

As a research team, we were originally interested in water sharing in chronic water insecurity conditions. Following Hurricane María, we extended this to examine resource sharing within social networks during the recovery period and to identify if and how Puerto Rican residents mobilized self-organized water-sharing networks to obtain safe and sufficient household water.

Research Questions

To understand how Puerto Rican households responded to acute disaster-induced water insecurity, we conducted in-person structured interviews with residents to learn about their water experiences before and in the months following Hurricane María. Six questions guided this research:

- To what extent did residents rely on sharing water with other households before and after Hurricane María?
- What reasons do residents cite for sharing water post-María?
- Was water sharing post-María planned or spontaneous?
- What network relationships (e.g., kin, neighbor, colleague) facilitated water sharing post-María?

- Was water sharing post-María guided by balanced or generalized reciprocity?
- How have experiences of water sharing post-María impacted residents' future disaster plans?

Study Context

Puerto Rico is an unincorporated territory of the United States located in the Caribbean, more than 1,000 miles from the continental United States (Fischbach et al., 2020), and is composed of three habited islands and several islets. In 2017, approximately 3.3 million people lived in Puerto Rico (Glassman, 2019), and the poverty rate was 44.5% (the highest in the United States). The median household income in 2017 was of $19,775, the lowest in the United States (Fischbach et al., 2020). Given local conditions, the population experienced significant outmigration, with more than 500,000 people (approximately 15% of the population) leaving between 2006 and 2019 (Cordero-Guzman, 2021).

Prior to the impacts of Hurricane María in 2017, Puerto Rico was facing serious economic and social challenges (Rivera, 2022). The economy had been in decline for more than a decade for a number of reasons: congressional decisions to "phaseout" (1996-2005) a tax credit that allowed United States Corporations to come to Puerto Rico without paying federal taxes; the Great Recession of 2008; and fiscal irresponsibility as seen through excessive borrowing and lack of economic transparency (Fisher & Horowitz, 2016; MacEwan, 2017). This cascaded into an unsustainable public debt of $70 billion. With corruption, mismanagement of funds, deferred maintenance, and climate conditions (e.g., increased groundwater salinity, increased humidity, and densely vegetated environment), this challenged investment and maintenance of critical public infrastructure such as electricity and water system (Fischbach et al., 2020; Fisher & Horowitz, 2016).

While United States Congress has plenary powers over Puerto Rico as part of its colonial relationship with the United States (Backiel, 2015), Puerto Rico has its own government system organized into three branches: executive, legislative, and judicial. The second level of administration in Puerto Rico is 78 municipalities, and these have the autonomy to develop their own budgets, engage in land-use planning, and engage in emergency management (Act 81 of 1991). Critical infrastructure services such as water and electricity are managed through public corporations (Fischbach et al., 2020). One public corporation, the Puerto Rico Aqueduct and Sewer Authority (PRASA), provides water and sewer services.

PRASA provides drinking water to approximately 97% of the population. The remaining 3% of Puerto Rican residents receive drinking water from small potable drinking systems (EPA, 2020). PRASA gets 80% of its water supply from surface water and 20% from groundwater (EPA, 2020). PRASA also serves 60% of Puerto Rico's wastewater systems; 40% comes from non-PRASA systems (EPA, 2020). Before Hurricane María, PRASA infrastructure was degraded and underfunded, experiencing high leakage rates and inadequate maintenance (Fischbach et al., 2020; Garriga-López, 2019; Lloréns & Stanchich, 2019). Despite being the primary source of drinking water, PRASA has repeatedly violated federal health standards, with up to 70% of the population receiving water that exceeds acceptable contaminant levels outlined in the Clean Water Act—more than any state or territory in the United States (Fedinick & Wu, 2017; Fischbach et al., 2020).

In the aftermath of Hurricane María, when residents were forced to find alternative water sources for household water security, many households purchased or received donated bottled water, drew water from rivers and springs, collected rainwater, or walked or drove to local water stations maintained by the military and municipalities (Dietrich & Garriga-López, 2018; EPA, 2020; Smyrilli et al., 2018). Residents relying on untreated water sources were exposed to pathogens in polluted rivers and streams, and this increased their risk of infectious diseases such as leptospirosis. Leptospirosis is endemic in Puerto Rico and of higher risk to those living near canals or river streams, given that overflows can contaminate the water with rat infestation (Andújar, 2018; Lloréns & Stanchich, 2019; Marinova-Petkova et al., 2019). A recent EPA (2020) report found 99% of the drinking water systems were restored nine months after the event. However, outside of cities, services were slower to reconnect, and water quality was questionable (Dietrich & Garriga-López, 2018; Ríos, 2018; Rodriguez, 2018).

Research Methods

Sampling

We conducted interviews with 81 residents located in three different communities on the western side of the island—peri-urban Rincón

Figure 1

Map of Puerto Rico in the Caribbean. Source: Peter Hermes Furian

(*n*=27), rural Añasco (*n*=27), and urban Mayaguez (*n*=27) (see Figure 1). These three municipalities demonstrated the geographical diversity of water accessibility and quality in María's aftermath based on access to rivers and streams and proximity to water distribution centers, among other factors. We purposively recruited participants who had experienced water insecurity following Hurricane María, maximizing age and gender variation across each sample.

Data Collection

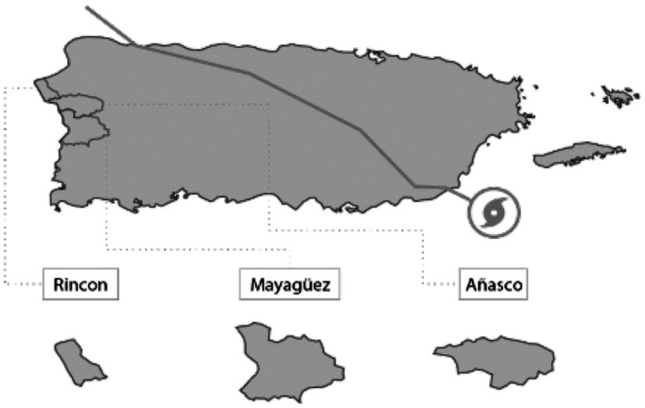
Roque conducted face-to-face interviews with participants in July 2019 in their language of choice. Interview questions captured qualitative data from open-ended questions and quantitative data from numerically rated items. The interviews also elicited each participant's post-disaster egocentric network (Faas and Jones, 2017; Sadri et al., 2018; Varda et al., 2009; Wasserman & Faust, 1994). We asked participants to list up to 7 people they received water from after Hurricane María, followed by questions about their ties and levels of social support. One limitation of this approach is the potential for recall bias, given that interviews were conducted 18 months after Hurricane María (Brashears et al., 2016). To account for this, we used vignette-style questions to promote memory recall of the events in a way that was sensitive to participants' experiences (Bradbury-Jones et al., 2014). In addition to interview data, we draw on field-notes from participant-observation conducted between December 2018 and January 2019 by Roque, who worked as a shelter administrator following Hurricane María. Part of their duties included distributing water to communities in Western Puerto Rico.

Data Analysis

Interview data were entered into Survey Monkey to create a database of both open- and closed-ended responses. Quantitative data were then downloaded. We used the statistical software Statistical Package for the Social Sciences (SPSS; IBM Corp., 2020) for Windows to compile descriptive

Figure 2

Map of Puerto Rico with Hurricane María Trajectory and Study Sites. Design by Jan Cordero



statistics on participants' experiences and network size in the wake of Hurricane María. For the analysis of open-ended interview responses, we developed codes to capture network composition (McCarty et al., 2019) and water-sharing dynamics (Wutich et al., 2018), following established deductive coding procedures (Bernard et al., 2016). Roque and two additional coders revised all codes until they reached high levels of intercoder agreement as measured by Cohen's Kappa (□ > .80). Our process for developing the codebook and applying codes is outlined in Beresford et al. (2022). We use pseudonyms here to protect participants' identities. A thematic analysis of coded interview data was then conducted. Themes identified included spontaneous water sharing, generalized reciprocity, transportation, personal networks, and employment type.

Findings

To what extent did residents share water with other households before Hurricane María vs. after Hurricane María?

Before Hurricane María, 98% of participants reported that they experienced no problems with access to water. Participants obtained drinking water via household taps, buying from water vendors, or going to the supermarket. We asked participants about water crises in the last 10 years (2009-2019) to understand previous experiences of water insecurity. Many participants had experienced an interruption in the water supply some time prior to María (71%). Less frequently, participants reported water crises experienced by residents, including water shortage (19%), water contamination (9%), and a refugee crisis[1] (1%). In the months before Hurricane María, water sharing was not a common community practice except in a few cases when people shared water with an elderly or disabled neighbor unable to get to the store.

Many participants spoke about stocking up on water for drinking purposes and saving water for sanitation when the media announced a hurricane warning two days before Hurricane María's impending arrival in Puerto Rico. Even so, the large-scale impact of Hurricane María on water access surprised all participants. In the wake of the event, interviewees stated that it took 30 minutes to three hours daily to fetch clean and safe water, depending on the extent they had to search for water, the distance to water sources, and the availability of transportation. Tony (urban Mayaguez) explained that finding water took him approximately two hours: "I was looking everywhere. Making lines in the municipal water tap, going to stores in Mayaguez, and getting water from a well from a friend of my brother-in-law." Other participants reported visiting municipal water tanks and receiving water from non-profit organizations, churches, or the military. They also collected water from rivers, streams, and wells and added drops of Clorox bleach to this water before drinking.

Eighty-six percent (*n*=70) of participants reported receiving water from others in their networks, ranging from once to several times (more than 10) until their water system was restored. Only 14% (*n*=11) of respondents did not receive water from any person outside of their household and instead received water from city center water tanks, the military, non-profit organizations, or faith-based organizations or retrieved their own water from river streams and/or wells. Many people reported back pain from carrying water and worry and emotional distress over water availability and collection in the months after the storm.

What reasons do residents cite for sharing water post-María?

While Puerto Rico has several water-related challenges, interviewees explained that the large-scale impact of Hurricane María and inefficiencies from formal agencies led to their engagement in water-sharing practices. Household water sharing was highly valuable for vulnerable populations and those with limited or no transportation. More specifically, water sharing was a critical coping

[1]Participant experienced water problems while displaced from home.

strategy for elderly folks, those with disabilities, or without a car. Tania (peri-urban, Rincón), an elderly woman, shared that she suffered from peripheral arterial disease, which prevented her from standing for long periods. She had to continually go to the municipal water tap to get water as she had small water collection devices. She explained that a neighbor would pick up water for his household, and "when I could not stand in line, he would tell me 'Look, stay at home, I'll take it [water] for you,' and so on several times, he gave me water from the municipal water tap." Other participants shared similar stories about receiving water or giving water to older folks and those with disabilities.

Gasoline stations also faced challenges in restoring their systems in the wake of María. This impacted those who relied on their cars to gather water. Having limited access to gasoline meant that they had to be strategic in the number of times they could go for water and the distance they were willing to travel, as Carlos (rural Añasco) explained: "Even though we had water here because we saved before María, we were fine for the first week and a half, but then things got complicated because to go get water, we had to fill up [the car] with gasoline, and the line for that was horrible." Transport challenges were worse for those who did not have the means to transport water. In these cases, social support and collective action were crucial, and community members would often stop and ask those without transportation if they needed anything. Water was often gifted and shared among those who collected it, and some participants spoke about how their neighbors would offer their trucks so others could pick up water from different localities.

Was water sharing post-María planned or spontaneous?

When participants were asked if they had made plans to share water with someone outside of their household prior to Hurricane María, most participants (78%, *n*=63) reported that they had not, but 22% (*n*=18) had anticipated water sharing. Participants who had developed plans for water sharing were motivated by a combination of preparedness culture and the uncertainty of the potential hurricane damage, given the impact of Hurricane Irma two weeks prior. Water-sharing plans were primarily with family members, particularly parents and neighbors. Broadly, the plans included saving as much water as possible to then exchange or access if needed and to be in communication after the event to help each other get more water. Participant Carmen (urban, Mayagüez) explained this: "I got ready with my neighbor…we made plans if any of us ran out of water to drink, we would help each other…. Because we imagined that a catastrophe was coming and we didn't know and well, to not have enough water after the event, it's better we had plenty." In contrast, participants who did not make plans to share water provided a number of reasons. For example, householders who reported that they had a cistern available or a nearby water stream did not feel the need to prepare with others. Others explained that their household members knew that they could visit the municipality plaza for water if needed. Others had saved water for the immediate aftermath of the event, which they considered would be sufficient. Lastly, for some participants, water came back relatively quickly after Hurricane Irma, and they did not feel the need to develop external plans; they assumed that water would come back quickly again. As a result, in the aftermath, most households had to engage in spontaneous water sharing. Rosa, an elder from the rural site, stated in relation to her neighbor that: "He would come home with gallons of water. He would arrive without warning and bring us batteries for the lantern. He did it more than four times." This experience was similar for those who made plans to share water, as they acted on their plans and gave water to individuals whom they had not earlier included (e.g., neighbors and co-workers).

What network relationships (e.g., kin, neighbor, colleague) facilitated water sharing post-María?

Of the 86% of participants who relied on water sharing after María, 27% (*n*=19) reported receiving water exclusively from kin ties, 15% (*n*=11) from neighbors, and less than 1% (*n*=2) from others (e.g., members of their church). Fifty-four percent (*n*=38) had a mix of types of ties in their water-sharing networks, and overall, 26% (*n*=18) of participants received support from at least one member with mixed ties, reflecting that they shared multiple social environments (e.g., neighbor and church member).

Employment was important in enabling inter-household water sharing post-María. Study participants recalled having, amongst their personal networks, connections to individuals who were employed in the government, supermarkets, and factories and who were business owners. These individuals had more opportunities to obtain water due to their work environments, as some of them worked "front line" jobs. Therefore, as Olga

(peri-urban Rincón) remarked about her friend: "I remembered that she worked at Econo [supermarket] and I stopped by her house to find out if there was water there or if she had any. She brought me two boxes from Econo when she could. It happened like four times. I gave her money to buy me the boxes of water." As Olga illustrates, their social relationship allowed her access to information about the availability of water.

Acknowledging women's particular challenges in post-disaster settings, we were interested to know if there was a statistical significance between participants' network size and gender. Performing a T-test showed that the difference in gender-based network size (p=0.049) was marginally statistically significant, with women's networks being more extensive than men's. This was later exemplified by narratives of household needs (e.g., cleaning and cooking), where women would reach out to or receive from their networks without having to ask. Miguel (rural Añasco) explained how he brought water to his daughter: "I would bring water to her, or she would come pick it up. This was weekly and I still do because she has a baby." This contrasted with men's experiences where they mainly expressed going out to seek water from different localities.

The use of personal networks to fulfill water needs was significant in these narratives. Personal network refers to a person, the people who are connected to this person, and their relationship with them (McCarty et al., 2019; Schweizer et al., 1998). Personal networks have demonstrated success in crisis management as a source for sharing resources and information (Schweizer et al., 1998). As a disaster response strategy, personal networks were instrumental in getting information on where to get water or about who could give them water. For example, Julio's network (rural Añasco) allowed him to access other networks that had available water. "Jorge and I are always together (friends), and we help each other.... He had contacts with other men who had a water tank, and he gave me from that water source." As Julio shows, his informal network of friends assisted him in sharing information on where to obtain drinking water, as well as a connection to access private water. In this sense, the use of personal networks for water access was of importance in coordination (e.g., organizing to get municipal water or collect water from rivers), decision making (e.g., intra-household decisions on how to use the available water, who should collect water, and from where to get water), and information sharing (e.g., knowing where and when to get water).

Was water sharing post-María guided by balanced or generalized reciprocity?

Typically, there was no expectation of immediate repayment during these water-sharing activities. Twenty-eight percent (n=23) engaged in balanced reciprocity, while 71% (n=58) engaged in generalized reciprocity. Following Sahlins' (1965) definition, generalized reciprocity includes "transactions that are putatively altruistic, transactions on the line of assistance given and, if possible and necessary, assistance returned" (p. 147). Carmen (urban Mayaguez) offered an example of generalized reciprocity when she explained that a family member checked in on her: "He came once when we needed water. He brought like 5-6 gallons of water. It was like falling from the sky because we were running out of water. He came to help us. And he didn't expect anything in return." Because communications towers were down, family, friends, and neighbors would consistently visit each other, and water offers were common during these visits. Also common were sporadic meetups during water collection, as Juan explained: "We saw each other in the barrio [neighborhood], and he reminded me that he had water for when I needed it. Three weeks later, I went several times for water."

How have experiences of water sharing post-María impacted residents' future disaster plans?

To understand if their previous experience impacted future emergency water preparedness, participants were asked two years after Hurricane María if they had made plans to give or receive water in case of another hurricane. As previously stated, only 22% of the participants engaged in water-sharing plans prior to María, while most participants (78%) had not made plans. Two years after María, 30% of the households expressed having plans; 70% had not. For participants with water-sharing plans, 88% had sharing plans with family members, and 12% had water-sharing plans with neighbors. For the households that did not have water-sharing plans, their reasons included: (1) have not thought about it, (2) current water availability, (3) forgotten, (4) nearby water source (e.g., well, river stream), (5) perception of not needing to plan at the time, and (6) hurricane threat not imminent.

Discussion and Implications for Research and Practice

With increasing extreme weather events and weakening physical infrastructures, communities without proper disaster mitigation and prepared-

ness plans will be more susceptible to water insecurity in the aftermath of climatic disasters. Disasters present challenges at different social and personal levels and often have compounding effects (García et al., 2021; Garriga-López, 2020). In Puerto Rico, the driving factors for post-disaster water insecurity consist of a combination of the lack of preparedness, hazard impact, aging infrastructure, interdependency on a vulnerable energy sector, and insufficient financial capital. Technical and economic failures shed light on the value of focusing and learning from the social dimensions of disaster response for future events.

This research demonstrates that water-sharing practices can be considered a form of disaster response. This work contributes to and extends past research on water sharing in chronically water-insecure communities (Rosinger et al., 2020; Wutich et al., 2018) by demonstrating how, in the wake of disaster, water sharing spontaneously emerges in previously water-secure rural, peri-urban, and urban communities. The role of social networks for water access was critical for coordination, decision making, information sharing, transportation, and, more broadly, as a coping mechanism for state failures. Participants showed strong ties (Granovetter, 1973) through their reciprocal exchanges and knowledge sharing about when and where to go for water. These findings support and expand on previous research that highlights that not only the connections among individuals but also the capability of these connections enable them to access a greatly needed resource (Messias et al., 2012; Norris et al., 2008). However, preparedness for future disasters is important because, depending on their severity, there might be fewer people and capabilities to help access life-saving resources, such as water. In the context of this research, the substantial proportion of people with water preparedness two years after María signals an urgent need to address disaster preparedness strategies around water access.

Water insecurity has detrimental effects on physical (e.g., infectious diseases, existing illnesses) and mental health (e.g., chronic worry, stress) that are only exacerbated in the context of a disaster. As a planned strategy, the use of social networks for water sharing has the potential to reduce these outcomes by opening a line of communication among ties in which water needs can be assessed and localities for safe and reliable drinking water can be identified. This will be of particular importance to reduce disparities for already identified vulnerable populations (e.g., women, children, elders, those with disabilities, and those without transportation). We show the importance of households taking part in water preparedness activities to offset institutional failures at the government level, such as through capacity building (e.g., training, educational campaigns, etc.) to develop and support social networks (see Eisenman et al., 2009). However, this does not relieve emergency management institutions and policymakers of their responsibility to develop large-scale disaster risk-reduction measures, mitigate vulnerability for their communities, and ensure water safety. Furthermore, there are structural challenges related to water quality, endemic diseases (e.g., leptospirosis), climate change impacts in freshwater resources, and the socioeconomic profile of the average Puerto Rican household. These factors all impact the availability or accessibility of safe and clean water.

Cities and towns can foster social infrastructure that can play a prominent role in disaster preparedness. Localized interventions increase citizen disaster preparedness (see Eisenman et al., 2009). Social networks can be purposefully utilized for disaster preparedness (Hossain & Kuti, 2010) to address structural barriers in disaster preparedness and response (Messias et al., 2012) and to engage community members in participatory activities around water preparedness. This is necessary to ensure that water-sharing networks will function well in a disaster context. Partnerships between emergency managers and local NGOs, faith-based organizations, community organizations, and community members can help build awareness and engage members who may be reluctant to participate. Training community volunteers who can assist emergency managers in reaching households may also be of value (see Lloréns & Santiago, 2018; Montano, 2019). Together, these strategies can help protect the human right to water in a post-disaster context.

Conclusions

Scholarly articles, newspapers, and reports have widely addressed the impacts of Hurricane María. However, the intersections of household water-sharing activities and networks in the wake of disaster are missing in such discussions. This work supports the emerging literature on water sharing by showing how it is used as a coping mechanism during and following an acute disaster. It also echoes the critical role that networks can play in addressing water insecurity. In Puerto Rico, the combination of aging infrastructure, geographical isolation, lack of emergency preparedness, and inadequate disaster

management strategies pushed affected individuals to engage in (mostly) spontaneous water-sharing practices and network building. As we have demonstrated, post-disaster networks consisting of family, friends, neighbors, and co-workers enabled participants to access water in María's wake. Water-sharing networks are an important—but understudied and underutilized—component of disaster response. We found that water sharing occurred in a reactive, rather than proactive, form. The implications are that water sharing should be planned and included in disaster preparedness plans. If water sharing is the dominant approach for coping with disaster-induced water insecurity, it must be at the core of disaster response.

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