

Perceptions of Climate Change in Puerto Rico before and after Hurricane Maria

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Abstract

This article analyzes the perceptions of Puerto Rican citizens of global climate change (GCC) before and after an extreme weather event, specifically Hurricane Maria (HM). The purpose of the current article is to evaluate Puerto Ricans' perceptions of the impact of extreme meteorological phenomena and of GCC before and after HM. This tropical cyclone entered the island as a category IV hurricane on September 17, 2017, causing enormous destruction, loss of life, and economic damage. In this study, two data samples were collected before and after HM struck Puerto Rico (PR) (the second sample was collected approximately six months after the hurricane). Surveyed citizens with general knowledge of GCC increased from 43% to 62%, which the researchers consider a small increase, considering the severe destruction caused by HM. This study also found that Puerto Ricans trust non-profit institutions and the scientific community more than state authorities. Furthermore, 85% of citizens believe that public policies on GCC should be directed by the state (federal, state, and municipal governments); this did not change after HM. In addition, this study found that the poor response of the federal and state governments to the destruction caused by HM increased citizens' trust in the scientific community.

Keywords

Puerto Rico, Hurricane Maria, Perception, Climatechange

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) warned in its first report, which was published in 1990, that one of the most serious consequences of global warming could be severe impacts on food security (Tigchelaara et al.,

2018). Such changes could contribute to human migration (Ritchie & Roser, 2020). This phenomenon has found its best example in Puerto Rico (PR), whose economy has been going through bankruptcy since 2008. The findings of this study were compared with previous findings published by other authors (Santos-Corrada & Méndez-Tejeda, 2017). Unfortunately, these problems were exacerbated by the impact of Hurricane Maria (HM), which struck PR on September 17, 2017. The extreme severity of the hurricane has been attributed to global warming (Ramos-Scharrón & Arima 2019; Keellings & Hernández Ayala, 2019). According to 2010 census data, the population of PR reached 3,721,525 citizens in 2008 (Censo, 2010). However, in just one decade, due to the economic crisis, the population decreased to 3,195,153 in 2018, representing an approximate loss of 14%.

Global warming is likely to cause catastrophic climate change, especially for the most vulnerable populations, which include small island states and island nations such as PR (Benjamin, 2010; Karmalkar et al., 2013; Nurse et al., 2014; Taylor et al., 2016; Howes et al., 2018; Stenntt-Brown et al., 2019; Mase et al., 2017). This impact can only be mitigated if action is taken immediately on a global scale. Developing states on small islands, including those of the Caribbean, are among the most vulnerable to climate change since they are more exposed than other nations to extreme weather events (McSweeney et al., 2010; Méndez-Tejeda, 2017; Timmermans et al., 2017; Melet et al., 2018).

Global climate change (GCC) is currently an important issue for both political agendas and public opinion, as it represents a serious threat to the survival of the human species (IPCC, 2014). Rising temperatures are not its only manifestation. Increased incidence of droughts and forest fires, rising sea levels, and adverse health impacts have also been reported, along with an increase in the frequency of extreme weather events around the world (Santos-Corrada & Méndez-Tejeda, 2017; Hugo, 2011; Hernández-Ayala et al., 2017; Herrera et al., 2021; Hember et al., 2017). These incidents generate significant social problems, including hunger, war, and migration (Hsiang et al., 2013; Adger et al., 2017; Abel et al., 2019).

The last three years of this decade broke records for extreme temperatures globally; 2019 was the hottest year ever recorded, and 2017 was just behind it (Menne et al., 2018; Cheng et al., 2020). Unfortunately, this trend is likely to continue, increasing the risks to the most vulnerable communities and facilitating the migration of both people and species (Hugo, 2011). (GCC is quickly transforming the world, and the next generations will experience a totally different environment from the one that existed in the last century (NCA4, 2018).

Meanwhile, people's perceptions of the risks of GCC vary substantially, both within countries and regions and between different countries. Individuals' perceptions of the risks of GCC are associated with economic and social status (Vischers & Siegrist, 2018; Drews & Van den Bergh, 2016). Climate change is a relatively unique risk; it is difficult for people to directly experience or even detect it at a purely perceptual or sensory level. In fact, research in the social and

behavioral sciences has shown that, although people may correctly perceive some long-term changes in weather conditions, psychological factors are often much more influential in determining public perceptions of the risks of climate change (Clayton & Manning, 2018). This is especially true for individuals who have been impacted by an extreme climatic phenomenon such as HM.

Several studies (Myers et al., 2013; Leiserowitz, 2006; Sörqvist & Marsh, 2019) have reported that cognitive, affective, social, and cultural factors strongly influence public perception of risk and that these factors often interact with each other in complex ways. However, a wide variety of cognitive, experimental, sociocultural, and demographic characteristics have been shown to impact risk perception (Sörqvist & Marsh, 2019; Weaver, 2016; Richards, 2018). Citizens' perceptions of the risks of climate change play a role in their commitment to and support for public policies aimed at mitigating GCC (Brody et al., 2008; Taylor et al., 2018; IPCC, 2013). This is critical for a country like PR, which, in addition to the catastrophe of HM, experienced an intense drought in 2011 and several heat waves in the summer of 2012 (Méndez-Lázaro et al., 2015), along with additional environmental impacts, such as the erosion of coastal areas (Barreto-Orta et al., 2019).

A survey (Borick Rabe, 2012), in the United States, confirms that public opinion about the existence and importance of global warming depends largely on public perceptions of recent local climatic variations. Early public recognition of the impacts of climate change is critical. Weather conditions can only be stabilized to maintain those of the Holocene period, the world in which civilization developed, if the rapid reduction of fossil fuel emissions begins as soon as possible (Hansen et al., 2008). Several studies have examined perceptions of climate change in PR; their findings suggest that, due to the island's vulnerability, public education on the impact of climate change and the development of public policies to mitigate GCC are urgently needed (Papoulis et al., 2015; Santos-Corrada & Méndez-Tejeda, 2017). The findings of the present study have been compared to those of a study conducted in Greece by (Papoulis et al., 2015). Other studies in PR provide a slightly more in-depth analysis of trends (ETI, 2018).

For more than two decades, various federal agencies, such as the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF), as well as state offices, churches, and non-governmental organizations (NGOs) in PR have offered educational campaigns (talks, workshops, courses, announcements, etc.) about climate change. These programs were implemented before HM, which destroyed 100% of the energy structure, causing an island-wide blackout that lasted more than three months. HM then led to the direct and indirect deaths of approximately 4000 people, and economic losses were estimated at USD \$94 trillion. The paper "Hurricane Maria: 12 hours that changed the history of a country" describes the country's situation before and after HM (Méndez-Tejeda, 2018, 2019; Kishore et al., 2018). Therefore, the purpose of the current article is

to evaluate Puerto Ricans' perceptions of the impact of extreme meteorological phenomena and GCC before and after HM.

2. Study Area

PR is in the center of the Caribbean (between latitudes 18° 31'N and 17° 55'N and longitudes 65° 37'W and 67° 17'W, between the Atlantic Ocean and the Caribbean Sea); in addition to the main island, the Commonwealth of PR includes five smaller nearby islands. The main island of PR is 180 km long and 65 km wide and encompasses a total land area of 11,700 km², making it the smallest island in the Greater Antilles (Santos-Corrada & Méndez-Tejeda, 2017). The highest point in PR is Cerro La Punta, a mountain peak in the Cordillera Central that is 1338 meters (4389 feet) high. Sierra de Luquillo is an isolated mountain range located in the northeastern part of the island. PR has a dense population within a small geographic area. Politically, PR is divided into 78 municipalities, including two municipal islands. First, confirm that you have the correct template for your paper size. This template has been tailored for output on the custom paper size (21 cm × 28.5 cm).

3. Method

3.1. Participants and Procedure

The participants included men and women over 21 years of age who live in PR. Two samples were taken, one from March to May 2017 (before HM) and one from February to May 2018 (after HM). Although convenience sampling was used, to improve representation, both samples included participants from throughout the entire island. A total of 1005 surveys were completed, 636 before HM and 369 after HM. The final sample included in the analysis consisted of 860 participants (56.51% women and 43.02% men). The survey was conducted in person. All participants provided voluntary informed consent. The questionnaires were stored in a box and then encoded onto an Excel sheet for subsequent data processing. The participants did not receive any incentive to take part in the study, and they answered the questionnaire anonymously.

Table 1, shows the results of (Santos-Corrada & Méndez-Tejeda, 2017), representing the original data collection carried out in 2016 (including Cronbach's alpha) with seven constructs for the metropolitan area of PR. Questionnaires were distributed and collected throughout the entire island from March to May 2017 (before HM); this sample comprises the original data (sample 1, Cronbach's alpha 1). The second sample was collected from February to May 2018 (after HM) (sample 2, Cronbach's alpha 2).

3.2. Profiles of Sample 1 Participants

Sample 1 comprises a total of 579 (**Table 1**) participants. All participants were aged 21 years and up; sample 1 consists of 58.2% females and 41.8% males. Of these, 32.6% (N = 189) were 21 - 24 years old, 15.7% (N = 91) were 25 - 34 years

Table 1. Profiles of participants. including gender, age and education level of respondents.

	Total	Gender		Age						Education (degree completed)						
		Females	Males	21 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65+	No school	Elementary school	Secondary school	High school	Bachelor	Graduate school	Technical degree
Sample 1	579	337 (58.2 %)	242 (41.8%)	189 (32.6%)	91 (15.7%)	103 (17.8%)	120 (20.7%)	39 (6.7%)	37 (6.4%)	20 (3.5%)	40 (6.9%)	40 (6.9%)	133 (23%)	109 (18.8%)	24 (4.1%)	211 (36.6)
Sample 2	281	149 (53%)	128 (45.6%)	79 (28.1%)	44 (15.7%)	63 (22.4%)	53 (18.9%)	16 (5.7%)	22 (7.8%)	2 (0.7%)	4 (1.4%)	5 (1.8%)	59 (21.0%)	71 (25.3%)	103 (36.7%)	35 (12.5%)

old, 17.8% (N = 103) were 35 - 44 years old, 20.7% (N = 120) were 45 - 54 years old, 6.7% (N = 39) were 55 - 64 years old, and 6.4% (N = 37) were over 64 years old.

In terms of educational attainment, the distribution was very broad: 3.5% (N = 20) did not complete elementary school, 6.9% (N = 40) completed elementary school, 6.9% (N = 40) did not complete high school, 23% (N = 133) completed high school, 18.8% (N = 109) had a college degree, 4.1% (N = 24) completed graduate studies (master or doctorate), and 36.6% (N = 211) obtained a technical degree or double degrees. Thus, 59.4% (N = 344) of the sample completed a high level of education.

3.3. Profiles of Sample 2 Participants

Sample 2 consisted of 281 participants over 21 years old; 53% (N = 149) were females and 45.6% (N = 128) were males. Of those, 28.1% (N = 79) were 21 - 24 years old, 15.7% (N = 44) were 25 - 34 years old, 22.4% (N = 63) were 35 - 44 years old, 18.9% (N = 53) were 45 - 54 years old, 5.7% (N = 16) were 55 - 64 years old, and 7.8% (N = 22) were over 64 years old.

In terms of educational attainment, the distribution for this sample was very broad as well: 0.7% (N = 2) did not complete elementary school, 1.4% (N = 4) completed elementary school, 1.8% (N = 5) did not complete high school, 21% (N = 59) completed high school, 25.3% (N = 71) obtained a college degree, 36.7% (N = 103) completed graduate studies (master or doctorate), and 12.5% (N = 35) obtained a technical degree or double degrees. Thus, 74.3% (N = 209) of the sample completed a high level of education.

SPSS software was used to analyze the data obtained from the questionnaire. The reliability of the data was checked using Cronbach's alpha. To prepare for a factor analysis, the Kaiser-Meyer-Olkin (KMO) test and the Bartlett sphericity test were performed. Finally, a factor analysis was conducted.

3.4. Data Analysis

- The data were collected, analyzed, and comparing to the findings of (Santos-Corrada & Méndez-Tejeda, 2017) (see **Table 1**). The economic crisis was not addressed in the questionnaire in the current work, which only includes seven themes. When we merged the data collected before HM, which in-

cluded participants from throughout the entire island, no significant differences were observed between alpha and alpha 1, demonstrating the consistency of the questionnaire.

- For both samples, Cronbach's alpha was calculated to measure the reliability of the instrument. For sample 1, Cronbach's alpha was 0.89; for sample 2, it was 0.88, indicating high reliability (**Table 2**) (Malhotra, 2010). Therefore, a factor analysis was used to reduce the dimensions of the instrument. Since Cronbach's alpha exceeded 0.87 for all individual items, it was not necessary to eliminate any of the items from the study (Méndez-Tejeda, 2019).
- The Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity were used to confirm the viability and correctness of the factor analysis. For both samples, the results were acceptable: The KMO was 0.88 for sample 1 and 0.83 for sample 2. Bartlett's test was 0.00 for both samples, so both samples are suitable for factor analysis (Méndez-Tejeda, 2019). The communalities table also shows that the values are very close to one, further confirming the suitability of these data for a factor analysis. The table of total variance shows that it is appropriate to reduce the model to 11 dimensions for both samples.

The standard deviation for sample 1 is between 0.607 and 1.475, and its variance is between 0.368 and 2.174. The standard deviation for sample 2 is between 0.791 and 1.585, and its variance is between 0.626 and 2.511. It is interesting to note that, in both samples, the question with the lowest deviation and variance is the one related to the degradation of water resources. One explanation for this could be that Puerto Rico experienced a period of significant drought in 2015. The question with the highest standard deviation and variance was the one related to concerns about climate change; one explanation for this could be a lack of knowledge about and interest in these issues.

4. Calculating the Percentage Difference

To determine the percentage difference, we used the mean value of the interval

Table 2. The table shows the themes addressed by the questionnaire. Note: Column 1: Seven themes. Column 3: Cronbach's alpha* values for the sample of (Tigchelaara et al., 2018). Alpha 1: Sample 1 (before HM, 2016/2017); Alpha 2: Sample 2 (after HM).

Themes	Items	Alpha*	Alpha 1	Alpha 2
Assessment of major environmental issues	7	0.736	0.742	0.745
Severity of impacts	5	0.780	0.805	0.791
Confidence	4	0.827	0.817	0.797
Responsibility	3	0.852	0.840	0.830
Action taken by state	10	0.872	0.881	0.829
Individual actions	10	0.686	0.726	0.715
Economic crisis	5	N/A	0.787	0.856
General assessment	3	0.650	0.622	0.691

in parentheses. The percentage difference was calculated by dividing the absolute value of the change between the two samples by the average of the values and multiplying the result by 100 (**Table 3**).

$$\% \text{ Different} = \frac{|E_1 - E_2|}{\frac{1}{2}(E_1 + E_2)} \times 100$$

Here, E1 (sample 1) and E2 (sample 2) are the values for the two samples for a given factor.

Table 1 shows the 11 factors. Factor 1, action taken by state, indicates that citizens believe that the state is responsible for establishing environmental policies. For this factor, the same exceptions apply before and after HM, and the average response for both samples was 4.25 (85%). In (Santos-Corrada & Méndez-Tejeda, 2017), this value was 83%.

Factor 3, which is related to the economy, shows that before HM, citizens had low expectations that the economy would improve; the results for sample 1 (before HM) were 47.6% (2.38). However, after HM, citizens became more optimistic: 59.2% (2.96) expected economic improvement, because they hoped that aid from federal and state governments would help improve their economic situation.

Factors 5 and 11 (the ambivalence factors) did not correspond to the same questions in samples 1 and 2, that is, the questions moved within the samples. Therefore, we have labeled them factor 5 (ambivalence factor 1) and factor 11 (ambivalence factor 2). This explains why these two factors have the highest

Table 3. Eleven themes identified by the factor analysis. Note: Sample 1 (before HM) shows the range of the answers to the questions; the maximum score on the Likert scale was 5, “completely agree.” The mean values are shown in parentheses. The third column shows the results for sample 2 (after HM). The fourth column shows the percentage difference between the samples. * In factor 7 of sample 2, only one item was answered.

Factor	Average Range (Sample 1)	Average Range (Sample 2)	% Difference
1) Government actions	3.96 - 4.51 (4.25)	3.94 - 4.55 (4.25)	0
2) Severity of impacts	4.24 - 4.52 (4.38)	4.35 - 4.56 (4.56)	4.02
3) Economy	1.90 - 2.85 (2.38)	2.53 - 3.38 (2.96)	21.72
4) Confidence	3.28 - 3.33 (3.31)	2.15 - 3.34 (2.75)	18.4
5) Ambivalence factor 1	3.92 - 4.63 (4.26)	2.18 - 3.25 (2.72)	44.13
6) Responsibility	4.07 - 4.46 (4.27)	3.94 - 4.20 (4.07)	2.39
7) Environmental problem	3.83 - 3.90 (3.87)	3.96*	2.29
8) Important problem	3.85 - 4.72 (4.27)	3.94 - 4.43 (4.19)	1.89
9) Individual actions	3.68 - 4.34 (4.01)	3.74 - 4.32 (4.03)	0.50
10) Knowledge	2.91 - 3.34 (3.13)	2.81 - 3.97 (3.39)	7.98
11) Ambivalence factor 2	1.74 - 4.13 (2.94)	3.81 - 4.04 (3.93)	28.82

percentages of difference at 44.13% and 28.82%, respectively.

The percentage of difference for the confidence factor is 18.48%; the sample before HM indicates greater confidence in the authorities, but this confidence decreased after HM. This can be explained as follows: Before HM, this question evaluated the expectation of trust, but after HM, the participants formed perceptions of that experience based on the actions of the authorities. Citizens lost confidence in these institutions, so the measures of the responses on the scale decreased from 3.31 to 2.75.

For the factor public relations knowledge of GCC, the average response for sample 1 (before HM) was 3.13; for sample 2 (after HM), it was 3.39. These values do not indicate a significant change, showing that citizens maintained the same level (medium) of knowledge about GCC after HM. This finding aligns with (Santos-Corrada & Méndez-Tejeda, 2017), who found that only 43% of respondents said they had knowledge of GCC; in the present survey, 62% said they had knowledge of GCC. The researchers consider this increase of 19% quite low considering the impact of HM.

5. Conclusion

Two samples of data collected in PR were analyzed to determine citizens' perceptions of GCC before and after HM. The most relevant findings are as follows:

- About 85% of participants believe that public policy on GCC should be directed by the state (federal, state, and municipal governments).
- **Figure 1** shows the results to the question: Is GCC one of the main environmental problems in Puerto Rico? As can be seen, there is no significant difference in the responses before and after HM.
- Participants in our second sample did not indicate increased concern about GCC despite having been personally impacted by an extreme meteorological phenomenon (see **Figure 2**).
- The poor response of the federal and state governments to HM led to an increase in citizens' confidence in the scientific community after HM (**Figure 3**).
- PR citizens have more confidence in NGOs and in the scientific community than in state authorities (**Figure 4** and **Figure 5**).

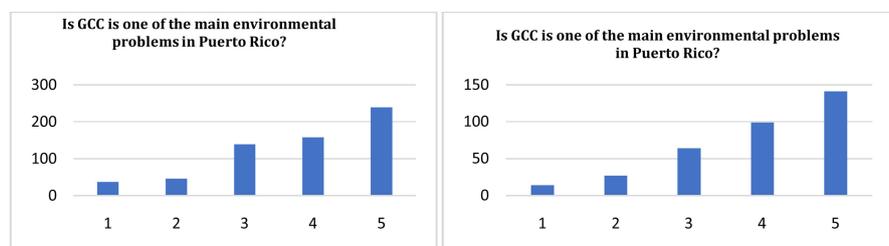


Figure 1. Is GCC is one of the main environmental problems in Puerto Rico? As can be seen, there is no significant difference in the responses before and after HM. Where the Likert scale 1 disagrees and 5 represents complete agreement.

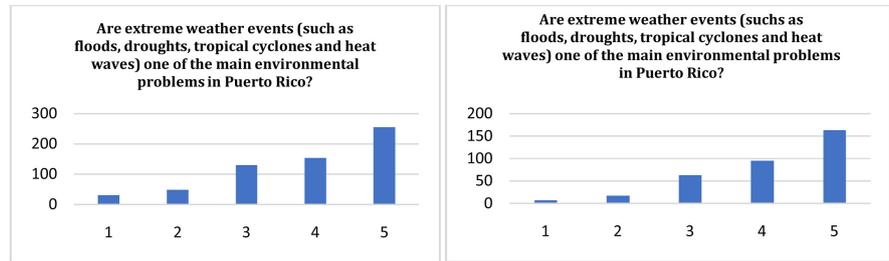


Figure 2. Are extreme weather events (such as floods, droughts, tropical cyclones and heat waves) one of the main environmental problems in PR? It is interesting that, despite having been impacted by an extreme weather phenomenon, participants do not indicate significant concern about these phenomena. Where the Likert scale 1 disagrees and 5 represents complete agreement.

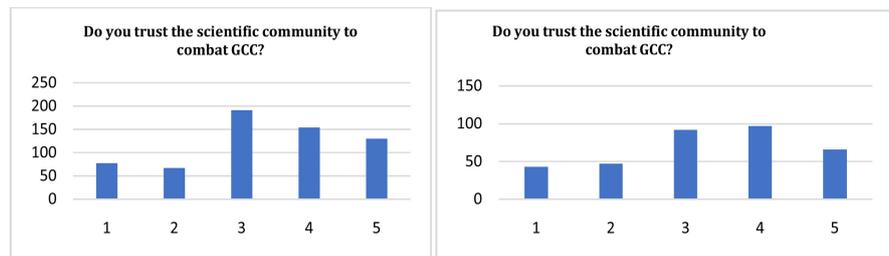


Figure 3. Do you trust the scientific community to combat GCC? Responses to this question indicate that trust in the scientific community decrease from sample 1 (before HM) to sample 2 (after HM). Where the Likert scale 1 disagrees and 5 represents complete agreement.

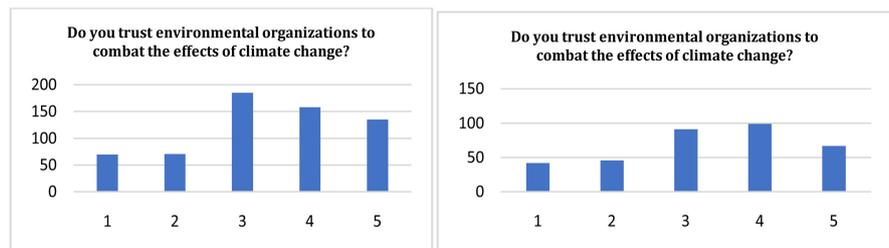


Figure 4. Do you trust environmental organizations to combat the effects of climate change? Responses to this question show that trust in non-governmental organizations (NGOs) increased from sample 1 (before HM) to sample 2 (after HM). Where the Likert scale 1 disagrees and 5 represents complete agreement.

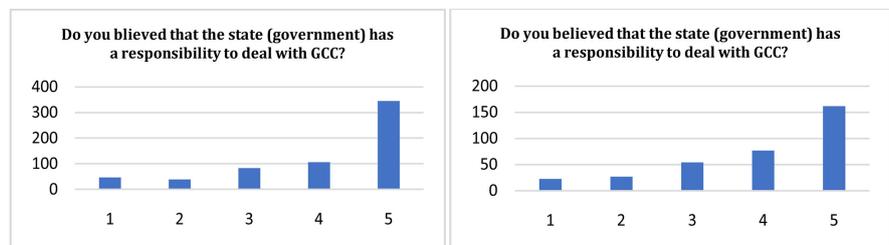


Figure 5. Do you believe that the state (government) has a responsibility to deal with GCC? Responses to this question indicate whether participants believed that the government should play a larger role in climate issues. Where the Likert scale 1 disagrees and 5 represents complete agreement.

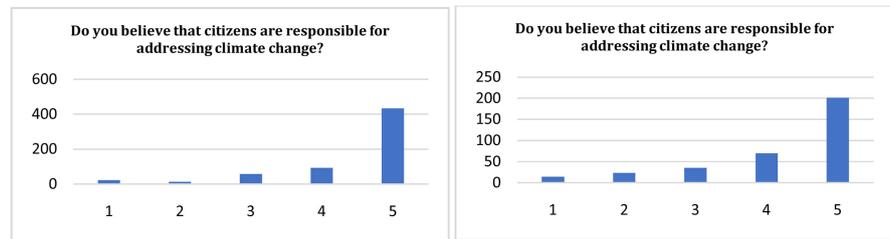


Figure 6. Do you believe that citizens are responsible for addressing climate change? After HM, participants indicated that individuals must take more responsibility for GCC. Where the Likert scale 1 disagrees and 5 represents complete agreement.

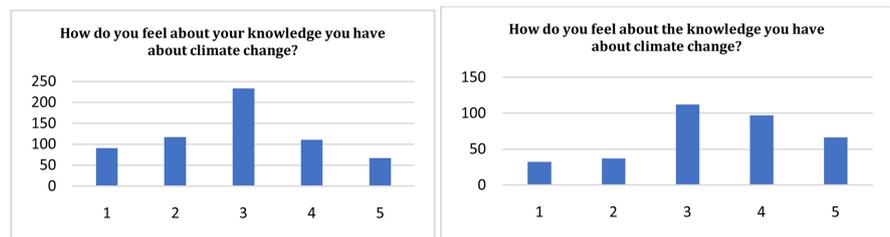


Figure 7. How do you feel about the knowledge you have about climate change? Here, respondents indicated a slight increase in knowledge about GCC after HM. Where the Likert scale 1 disagrees and 5 represents complete agreement.

- The mismanagement of the crisis caused by HM and the number of indirect deaths due to HM (Méndez-Tejeda, 2018, 2019; Kishore et al., 2018) negatively impacted citizens' trust in state and federal authorities.
- PR citizens are likely to be willing to take individual action to lessen the impact of GCC if they are encouraged to do so (Figure 6).
- Citizens' knowledge about GCC increased from 43% in 2016 (before HM), (Santos-Corrada & Méndez-Tejeda, 2017), to 62% in 2017 (after HM). Figure 7 shows an increase in understanding the impact of CCG on PR. Which the authors consider this increase to be very small considering the devastating impact of the MH and the intense CCG education campaigns undertaken by various government organizations (Figure 7).

Limitations and Recommendations

This study has some limitations. First, communications networks in PR were devastated by HM, which made data collection difficult. It is recommended that both governmental and non-governmental institutions refocus their GCC education campaigns since our data indicate that Puerto Ricans' knowledge of the possible impacts of climate change is not consistent with the investment and effort of current educational campaigns.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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