

An Assessment of Public Perceptions of Climate Change Risk in Three Western U.S. Cities

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ABSTRACT

Risk perceptions influence individual and collective action related to climate change, and there is an important gap between public and expert perceptions of climate change risk, especially in the United States. Past studies have found that on average 40% of the American public believe climate change will affect them personally. We contribute a study of climate change risk perceptions in the metropolitan areas of three western U.S. cities (Denver, Colorado; Las Vegas, Nevada; Phoenix, Arizona), assessing overall patterns and drivers. A representative mail survey ($N = 786$) of the general public in these cities revealed that 60% of respondents identified climate change as personally risky, with the perception that it will impact either their family or their city in the next 30 years. Our results indicate that the gap in risk perceptions between the public and experts may be decreasing, although we discuss several limitations and reasons why this result requires further investigation. Using regression models, we analyze factors that are hypothesized to drive risk perceptions and discover that pro-environmental worldview and perceived personal responsibility are the most influential predictors. We discuss the implications of our results for fostering collective action to address climate change in dry, western U.S. metropolitan areas.

1. Introduction

Understanding how the public perceives climate change impacts is critical to motivating successful adaptation and mitigation efforts (Leiserowitz 2006; Lorenzoni and Pidgeon 2006). In the United States, approximately 40% of the public believes that climate change will impact them personally, while most believe it will harm people globally (Marlon et al. 2016). In western nations more generally, this lack of personal risk perception has been identified as a barrier to engaging the public in climate change adaptation and mitigation efforts (Weber 2011). Evidence suggests that people's climate change risk perceptions, often formed via direct experience with projected impacts such as

intensified flooding, are associated with supporting or participating in individual or collective solutions (Niles et al. 2013; Spence et al. 2011). As the United States is the second largest carbon dioxide emitter globally (World Bank 2017), understanding how Americans perceive climate change risks and how they subsequently address them has global consequences (Gardiner 2011; Wilbanks and Kates 1999). To improve our understanding of the American public's climate change risk perceptions, this article presents findings from a representative survey of the public in the metropolitan areas of three western U.S. cities. Responding to scientists' and decision-makers' need for subnational data on climate change risk perceptions (Howe et al. 2015), we analyze whether residents in Denver, Colorado; Las Vegas, Nevada; and Phoenix, Arizona, regard climate change as personally harmful, their risk perceptions related to more frequent or intense extreme weather events, and the drivers of these risk perceptions. We conclude with the implications for collective action related to climate

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change and efforts to engage the public in addressing climate change risks.

a. The importance of risk perceptions: Risk perceptions and collective action

In this article, when we use the term “risk perceptions,” we are referring to increasing perceptions of risk (i.e., someone with greater risk perception thinks climate change poses greater risks) and risk perceptions related to climate change (unless stated otherwise). Risk is a subjective construct often conceptualized as potential damage or harm (Slovic 2000). The public uses a complex suite of factors to evaluate perceived risk from climate change, including trust, values, experience, and emotion, among others (Leiserowitz 2005). Understanding public perceptions of climate change risk is critical to informing the design of successful related policies (Drews and Van den Bergh 2016).

To explore risk perception and its relationship with addressing climate change, we highlight three concepts related to risk perception and collective action. First, climate change is a collective action problem. Second, risk perceptions influence collective action for addressing environmental issues, including climate change, and third, new institutions are required to support climate change collective action.

Addressing global climate change is a collective action problem (Barrett and Dannenberg 2014), where negative outcomes can be reduced if many actors decide to take actions that are costly in the short term. Collective action is voluntary behavior taken to address a shared issue, by either a group or a representative of a group, to improve group conditions (Bamberg et al. 2015). In the absence of a comprehensive, legitimate, and monitored global climate change treaty, polycentric collective action is a promising pathway to make a difference in adaptation and mitigation efforts (Ostrom 2010). Polycentricity involves governance by independent actors at multiple scales, where actors can seek solutions at the scale matching an issue. A key feature of polycentricity is the opportunity of actors across scales to learn from each other about the effectiveness and implementation of diverse strategies. Polycentric approaches help build the trust necessary for cooperation to address climate change (Cole 2015). The high levels of trust needed to solidify a climate change mitigation policy among the largest greenhouse gas emitters in the world are unlikely to be developed in time to avoid the necessity for significant climate change adaptation. Polycentric action to address climate change at multiple subnational scales (such as cities and states) simultaneously (Ostrom 2010) is particularly salient in the United States where national climate policy is highly politicized (Cooper 2018).

Risk perception is critical as a driver of collective action for many human-environment issues, including climate change adaptation and mitigation (Church et al. 2018; Shin and Choi 2015). Early studies indicated that risk perception was an important variable in models of climate change-related behaviors (O'Connor et al. 1999). Researchers have since discovered more evidence that risk perceptions positively predict people's support of climate change-related policies, behavioral intentions, and behaviors to address climate change (Arbuckle et al. 2015; Lubell et al. 2006; Semenza et al. 2008). Importantly, risk perception is necessary, but insufficient, for most people to address climate change (Arbuckle et al. 2015; Sousa-Silva et al. 2018), and risk perceptions further constrain broader sociopolitical efforts (Leiserowitz 2006). Americans that believe climate change will primarily affect people from distant places or that climate change impacts will not occur are less likely to support adaptation policies (Singh et al. 2017). In addition to risk perception, social identity, reliance on natural resources, self- and collective efficacy, and perceived norms surrounding participation also drive collective action related to climate change (Bamberg et al. 2015; Rees and Bamberg 2014).

Researchers have called for new institutions to foster collective efforts to confront climate change for decades (e.g., O'Riordan and Rayner 1991). Institutions, as rules, norms, and strategies that shape decision-making and behaviors, influence not only the climate risks that people face but also their responses (Agrawal 2010). New institutions that incentivize the development of both public and private relationships (to facilitate trust building) between local organizations and governments are necessary to develop the adaptive capacity to collectively address climate change (Pelling et al. 2008).

b. Unpacking the drivers of climate change risk perception

A wide range of variables predict people's risk perception, including deeply held cultural and ideological factors such as political and environmental worldview (Weber 2010). A greater pro-environmental worldview, for example as measured by the New Ecological Paradigm (NEP) scale, has been associated with greater risk perception and belief in anthropogenic climate change (Dunlap 1998; Ziegler 2017). Other ideological measures, such as market environmentalism (e.g., Perron et al. 2001) and conservative and liberal political values, also influence risk perception. Members of the U.S. public identifying as conservative or Republican have lower risk perception related to general climate change impacts (Egan and Mullin 2017; McCright and Dunlap 2011), but the relationship between risk perception and

political orientation may be different when risk perceptions of specific local climate change impacts are examined (Smith et al. 2016). Greater trust in government actors and institutions is correlated with greater support of climate change adaptation and mitigation policies, but the relationship between trust in government and risk perception is less clear (Lorenzoni and Pidgeon 2006).

Public risk perceptions do not appear to be driven by knowledge deficits, but by diverging values (Weber and Stern 2011). Most risk perception research has focused on analyzing data on knowledge related to general awareness of climate change and its causes (van der Linden 2015). Kahan et al. (2012) discovered that greater scientific literacy and knowledge do not lead to greater risk perception and instead can polarize environmental values, and Shi et al. (2016) found that how knowledge is measured (e.g., assessing knowledge of causes of climate change vs physical characteristics) influences its relationship to risk perception.

Greater psychological distance—in this case an individual feeling that climate change will impact people from distant, “other” places—is associated with less concern about climate change risks and reduced support of adaptation policies (Singh et al. 2017). Personal experience with extreme events that are projected to increase with climate change is associated with increased risk perception (Spence et al. 2011; Weber 2011). Additionally, individuals with higher levels of perceived personal responsibility have greater risk perceptions (Kellstedt et al. 2008). Although sociodemographic variables such as gender, education, income, family structure, geographic location, and job position have been found to predict risk perception more broadly, they often have weak associations, if any, with climate change risk perception (Stedman 2004).

We hypothesize that greater pro-environmental worldview and perceived personal responsibility for engaging with issues related to climate change will positively predict risk perception. Focusing on dimensions of knowledge beyond general awareness of causes and impacts, we also hypothesize that procedural knowledge about how to participate in or implement actions to address climate change related issues will influence risk perception. Last, we hypothesize that an individual’s trust in government will be positively associated with risk perception and that sociodemographic variables will not directly influence risk perception.

c. Local risk perceptions, local responses

Contributing to the need for metropolitan-scale information on public risk perception, we analyze data from three arid or semiarid western U.S. metropolitan

areas (Denver, Las Vegas, and Phoenix). The Las Vegas and Phoenix metropolitan areas are characterized by desert climates, while Denver is semiarid grassland. Southwestern cities like Denver, Las Vegas, and Phoenix are anticipated to become hotter and drier (Garfin et al. 2014). These metropolitan areas are already experiencing challenges related to climate change including water availability (Gober 2014; Meko and Woodhouse 2011; Salvaggio et al. 2014) and the urban heat island effect in Phoenix (Guhathakurta and Gober 2007). Additionally, all three areas rely on the Colorado River basin for a significant portion of their municipal water supply, which is projected to experience prolonged and intensified droughts (Cook et al. 2015). Vulnerability to climate change is a human-produced trait; that is, communities are not inherently vulnerable to climate change impacts (Kelly and Adger 2000). As decision-makers evaluate potential adaptation and mitigation strategies, understanding risk perception among the public depending on the Colorado River may inform socially acceptable policy options that are more apt to succeed in reducing the vulnerability of these areas.

2. Methods

a. Denver, Las Vegas, and Phoenix

This research on climate change risk perception is part of a larger study exploring public support for, and attitudinal drivers of, sustainable water governance transitions and support for transformational water management strategies in Denver, Las Vegas, and Phoenix. We define transitions as incremental changes that move a system toward a new state and transformational strategies as those that are radical in the context of the status quo of the system and aid in system transition (Loorbach et al. 2017). The survey we administered was framed as “water in the west” and broadly asked the respondents questions about their perception of the need for water management changes to achieve sustainability principles tied to equity, ecology, and economy [based on the principles in Wiek and Larson (2012)]. We selected the metropolitan areas of Denver, Las Vegas, and Phoenix as part of a comparative case study approach (Seawright and Gerring 2008; Yin 2017). The three metropolitan areas share key similarities (e.g., reliance on Colorado River water; projected future temperature changes) but they also differ on variables that may influence climate change risk perception (e.g., upper vs lower basin; average annual temperatures and precipitation; water governance structures). Analyzing these three cases informs our understanding of whether there are primarily similarities or divergences in risk perception and potential

pathways for addressing climate change in dry, western U.S. metropolitan areas.

b. Survey method

This research was approved by Arizona State University's Institutional Review Board (STUDY00007342). We administered a mail survey to 3000 households, 1000 from each city's census-based metropolitan statistical area (MSA). The sampling frame was the Delivery Sequence File including all residential delivery addresses serviced by the United States Postal Service. The simple random sample was drawn from households in our MSAs within the frame and the survey incorporated four waves to maximize response rates (Dillman et al. 2014; Groves et al. 2011). The first mailing in January 2018 included the complete questionnaire/cover letter and a \$2 incentive. This was followed 2 weeks later by a postcard reminder and two subsequent mailings of the full questionnaire (no incentives) to nonresponders. We received 786 completed surveys (Denver: 253; Las Vegas: 224; Phoenix: 309). To calculate response rates, we followed procedures recommended by the American Association for Public Opinion Research (AAPOR 2016). Adjusting for 187 undeliverable surveys, the overall response rate was 27.9%, consistent with ranges for unsolicited, mail-based social surveys [see Whitmarsh (2009) and Shih and Fan (2008)]. The margin of sampling error for the overall sample is $\pm 3.5\%$ at the 95% confidence interval and the sampling errors for the study sites are $\pm 5.6\%$ for Phoenix, $\pm 6.2\%$ for Denver, and $\pm 6.5\%$ for Las Vegas. In comparison with U.S. demographic profiles, our responses were disproportionately highly educated; white, non-Hispanic; and older (Table 1). Given this, we weighted our descriptive results by American Community Survey demographic information for each of the MSAs (U.S. Census Bureau 2016). Weights were calculated using raking, an iterative process that was continued until weighted frequencies and population frequencies converged (Kalton and Flores-Cervantes 2003). The following variables were included in the procedure: percent white, black, Asian, Native American, Pacific Islander, other, Hispanic; education (percent with bachelor's degree or higher); and age (percent 65 or older).

c. Variables and statistical analyses

The survey included two four-item questions on risk perception (Table 2). The dependent variables for the regression analyses are scales created from these two questions (the scales are presented in section 3) and a binary variable coded from the first two items of question 1 in Table 2. The first question in Table 2 addresses certainty about climate change risk perceptions on the

scale of societal transitions, asking respondents to focus on impacts over the next 30 years. The independent variables analyzed include environmental world view, perceived personal responsibility, procedural knowledge, trust in government, and sociodemographics (Table 2). Given the Colorado River context, questions related to perceived personal responsibility and procedural knowledge are framed in the context of water management as it relates to climate change. Water management is one of the most salient environmental issues in these metropolitan areas, and intersects with climate change risk perceptions (Pahl-Wostl 2007). The variables we analyze, particularly the water-management related items, can be modified to understand public perceptions of climate change risk and inform decision-making in other systems. We do not analyze political orientation because we do not have data at the household level for our sample. NEP and trust in government questions may be capturing some of the underlying variation explained by political orientation, but the omission of political orientation is a limitation of this study.

We examined the dataset for violations of the assumptions of linear regression, including normality of the distribution of the dependent variables with density plots, multicollinearity, and outliers. There were no major deviations from normality or multicollinearity issues with the variables. The dataset is structured in two levels: household respondents nested into three metropolitan areas. Given the multilevel structure, we first conducted hierarchical linear regression. However, there was not enough variation in the dependent variables between metropolitan areas for the mixed modeling approach to be statistically valid (Raudenbush and Bryk 2002), as the best estimate for the random intercepts was consistently zero. We present the results of a binary logistic regression and two stepwise linear regressions to examine our hypotheses and explore which independent variables provide the best model fit.

3. Results

a. Overview of climate change risk perception

Across the three metropolitan areas, 51.7% of residents are very to extremely certain that climate change will impact their family and 58.7% are concerned that climate change will impact their town or city. Table 3 presents climate change risk perception by city (in Table 3, we combined the upper and lower ends of the Likert scale for question 1 in Table 2).

Across the three metropolitan areas, residents are most certain that their town or city will experience extremely large to large negative impacts from droughts

TABLE 1. Comparison of this survey with the American Community Survey (ACS) demographics (percentages).

	Denver		Las Vegas		Phoenix	
	ACS 2016	This survey	ACS 2016	This survey	ACS 2016	This survey
Asian	3.5	7.5	6.5	12.1	3.5	4.2
Black	9.8	5.1	11.8	12.1	6.8	4.5
Native American	0.9	2.0	0.6	5.4	2.0	2.3
Pacific Islander	0.1	1.6	0.6	4.5	0.2	1.0
White	77.0	81.4	64	71.4	72.6	80.9
Other	5.4	6.7	11.8	6.7	11.5	8.1
Hispanic	30.8	5.9	32.2	10.3	41.8	9.7
Education (percent with bachelor's degree or higher)	46.7	62.1	19.9	42.8	24.7	53.4
Age (65 and older)	10.9	31.2	13.9	36.2	9.8	35.0

(69.7%) and heatwaves (71.7%), reflecting the arid and semiarid context of our respondents. Table 4 presents these risk perceptions by city (in Table 4, we combined the upper and lower ends of the Likert scale for question 2 in Table 2).

b. Scale creation and ANOVA

Prior to regression, the consistency of five scales was tested, and the scales were internally valid (Cronbach's alpha values for shortened NEP = 0.768, perceived responsibility = 0.633, procedural knowledge = 0.653, climate change local global risk = 0.969, and climate change extreme events = 0.926). The climate change local to global risk scale includes the four items from question 1 in Table 2 and the climate change extreme events scale includes the four items from question 2 in Table 2. One-way analysis of variance (ANOVA) tests of the two dependent variable scales revealed no significant differences between the three metropolitan areas on the climate change extreme events scale (Table 5). Thus, we only examine the post hoc tests for the climate change local to global risk scale (Table 6). Las Vegas residents have statistically significantly higher risk perceptions than Phoenix residents (Table 6), but the effect size is small (eta squared = 0.009).

c. Stepwise regression

We analyzed two stepwise linear regression models. In the first model, the dependent variable is the climate change local to global risk scale; in the second model, the dependent variable is the climate change extreme events scale.

1) CLIMATE CHANGE LOCAL TO GLOBAL RISK SCALE

On the basis of our hypotheses, we entered the following independent variables into the stepwise procedure: personal responsibility scale, environmental worldview scale (NEP), personal knowledge scale, trust in

government scale, gender, education, and race/ethnicity. The following variables predicted responses: environmental worldview, perceived personal responsibility, gender, and procedural knowledge. The best model fit was achieved (adjusted $R^2 = 0.561$) when all four variables were included (Table 7). However, almost all of the variance in the model was explained by the NEP and personal responsibility scales alone.

Pro-environmental worldview (NEP scale) and perceived personal responsibility positively predict overall risk perception, with pro-environmental worldview having a greater effect (Table 8). Identifying as male and reporting higher procedural knowledge about water issues relevant to climate change negatively predict overall risk perception, although the relative effects of gender and procedural knowledge are weak.

2) CLIMATE CHANGE EXTREME EVENTS SCALE

Based on our hypotheses, we entered the following independent variables into the stepwise procedure: personal responsibility scale, environmental worldview scale (NEP), personal knowledge scale, trust in government scale, gender, education, and race/ethnicity. The following variables predicted responses: environmental worldview, perceived personal responsibility, procedural knowledge, and gender. The best model fit was achieved (adjusted $R^2 = 0.510$) when all four variables were included (Table 9). However, most of the variance in the model was explained by the NEP and personal responsibility scales alone.

The regression results are similar to the climate change local to global risk model, except procedural knowledge is a stronger predictor of the responses on the climate change extreme events scale (Table 10). Pro-environmental worldview (NEP scale) and perceived personal responsibility positively predict risk perception related to extreme events, with pro-environmental worldview having a greater effect. Reporting higher procedural knowledge about water issues relevant to

TABLE 2. Overview of survey questions and variables.

Question stem	Items	Response scale	Corresponding variable(s)/construct	Variable type	Question source
In the next 30 years, how certain are you that changes in the climate will have a negative impact on...	You and your family Your town and your city Your state People across the world	5-point Likert, labeled “Not at all,” “A little,” “Somewhat,” “Very,” or “Extremely”	Climate change local to global risk scale (all items); climate change personally risky	Continuous (climate change local to global scale); binary (climate change personally risky—coded 1 if Likert response was Very or Extremely on items 1 or 2)	Adapted from Howe et al. (2015)
Thinking of life in your town or city, to the best of your knowledge, how much of an impact will a changing climate have on...	Drought or water shortages Higher likelihood of storms and floods Higher severity of storms and floods Increased likelihood of heatwaves	5-point Likert, labeled “No impact,” “A small impact,” “A moderate impact,” “A large impact,” or “An extremely large impact”	Climate change extreme events scale; risk perceptions related to magnitude of extreme events	Continuous	Adapted from Howe et al. (2015)
The following are statements about the environment and society. Please indicate how much you agree or disagree with each statement.	We are approaching the limit of the number of people the earth can support. The balance of nature is very delicate and easily upset. Despite our special abilities humans are still subject to the laws of nature. If things continue on their present course, we will soon experience a major ecological catastrophe.	5-point Likert, labeled “Strongly disagree,” “Mildly disagree,” “Neutral,” “Mildly agree,” or “Strongly agree”	NEP scale; environmental worldview	Continuous	Four-item version of the NEP questionnaire (López-Bomilla and López-Bomilla 2016)
How much would you say you know about how to...	Participate in water resource decision-making for your community Conserve water outdoors, such as installing drought tolerant plants	5-point Likert, labeled “Nothing at all,” “A little,” “Some,” “Quite a bit,” or “A great deal”	Procedural knowledge scale; procedural knowledge related to water decision-making and site-relevant conservation	Continuous	This survey
How much personal responsibility do you feel for...	Participating in local decision-making about water Conserving water in your city, even if other water users do not do anything to conserve water	5-point Likert, labeled “None,” “A little,” “A moderate amount,” “Quite a bit,” or “A great deal”	Personal responsibility scale; perceived personal responsibility related to water decision making and conservation	Continuous	Item 1 developed for this survey; item 2 adapted from Jorgensen et al. (2013)

TABLE 2. (Continued)

Question stem	Items	Response scale	Corresponding variable(s)/construct	Variable type	Question source
In your opinion, how often can...	The federal government in Washington D.C. be trusted to do what is right Your town or city government be trusted to do what is right	5-point Likert, labeled "Never," "Rarely," "Sometimes," "Very often," or "Extremely often"	Trust in government scale	Continuous	American National Election Studies (2016) survey
Thinking about water management for your town or city...	To what extent would you support or oppose residents, such as yourself, working with local water managers to make decisions	5-point Likert, labeled "Strongly oppose," "Somewhat oppose," "Neutral," "Somewhat support," or "Strongly support"	Not included in models; frequencies presented in Table 12	Continuous	This survey
What is your gender?	—	"Female," "Male," or "Prefer not to answer"	Gender	Binary (Female coded 0; Male coded 1)	
Do you consider yourself to be Hispanic, Latino(a), or Chicano(a)?	—	"Yes" or "No"	Race/ethnicity; identification as a minority race or ethnicity	Binary (coded as part of the ethnic/racial minority variable—Yes coded 1; No coded 0)	
What racial or ethnic groups do you identify with? Please check all that apply.	—	"White," "Black or African American," "Asian," "American Indian or Alaska Native," "Native Hawaiian or Other Pacific Islander," and/or "Other"	Race/ethnicity; identification as a minority race or ethnicity	Binary (coded into an ethnic/racial minority variable—white coded 0; all other responses coded 1)	
What is the highest level of schooling you have completed?	—	"Grades 1–8," "Grades 9–11," "High school diploma," "Some college but no degree," "Community college degree," "Vocational or technical school degree," "Bachelor's degree," or "Graduate or professional school such as Master's degree, Ph.D., M.D., or J.D."	Education	Categorical	

TABLE 3. Reported risk perceptions by city (percent of respondents): “In the next 30 years, how certain are you that changes in the climate will have a negative impact on. . . .”

	Not at all–A little	Somewhat	Very–Extremely
You and your family			
Denver	20.1	23.9	55.8
Las Vegas	21.8	30.5	47.7
Phoenix	21.1	28.5	50.4
Your town or city			
Denver	19.3	20.1	60.6
Las Vegas	17.8	23.4	58.8
Phoenix	22.6	20.5	56.9
Your state			
Denver	17.8	18.2	64.0
Las Vegas	18.3	19.2	62.5
Phoenix	19.3	21.3	59.4
The world			
Denver	12.6	15.9	71.4
Las Vegas	14.4	17.0	68.6
Phoenix	12.7	17.3	69.9

climate change and being male negatively predict risk perception related to extreme events, although the relative effects of procedural knowledge and gender are weak.

d. Logistic regression of personal risk perceptions

Finally, we analyze what predicts whether respondents view climate change as personally risky. “Personally risky” refers to respondents that answered “very” or “extremely” on items 1 or 2 of question 1 in Table 2 (i.e., respondents that perceive risk to their family or city). As in the overall risk perception model, environmental worldview (NEP scale) and perceived personal responsibility positively predict risk perception (Table 11). Additionally, education is a weak negative predictor. In examining the odds ratios, it is seen that the odds of a respondent with a greater pro-environmental worldview perceiving climate change as personally risky are 8.039 as high and the odds of a respondent with greater perceived personal responsibility perceiving climate change as personally risky are 1.829 times as high. The Nagelkerke R^2 for the model is 0.531.

e. Summary

We found that 60.1% of our overall sample perceived climate change as personally risky, greater than the U.S. national average of 40% from recent studies (Marlon et al. 2016). The most recent Yale climate opinion maps [Marlon et al. (2016), using the method from Howe et al. (2015)] find 41% of individuals in the Denver MSA, 44% of individuals in the Las Vegas MSA, and 39% of individuals in the Phoenix MSA perceived that climate change would harm them personally. Comparatively,

TABLE 4. Reported risk of negative impacts from extreme weather events by city (percent of respondents): “Thinking of life in your town or city, to the best of your knowledge, how much of an impact will a changing climate have on. . . .”

	No–Small	Moderate	Large–Extreme
Drought			
Denver	15.8	13.5	70.7
Las Vegas	8.4	15.5	76.1
Phoenix	17.7	17.6	64.7
Frequency of storms and floods			
Denver	26.3	23.2	50.4
Las Vegas	27.9	21.4	50.7
Phoenix	29.8	31.1	39.1
Severity of storms			
Denver	26.7	21.7	51.6
Las Vegas	28.3	19.7	52.0
Phoenix	31.6	21.7	46.7
Heatwaves			
Denver	18.5	13.4	68.2
Las Vegas	12.5	13.7	73.8
Phoenix	14.0	12.8	73.3

the perception of climate change as impacting respondents was greater in our three MSA samples: 62% of Denver respondents, 57% of Las Vegas respondents, and 60% of Phoenix respondents reported climate change would impact their family or their town/city. Our sample perceived specific climate change risks, including heatwaves, drought, and severe storms. Additionally, we found that a majority of the survey respondents (69%) reported a desire to work with water managers on decisions related to climate change risks but that 69% also reported a dearth of knowledge about how to do so (Table 12). Also, 52% of respondents could “rarely” or “never” trust the federal government, and a further 40% could only trust it “sometimes” (Table 12).

Consistent with our hypotheses and previous research, pro-environmental worldview and perceived personal responsibility were the strongest positive predictors of risk perception, for both overall risk (all four items in Table 2) and personal risk (items 1 and 2 in

TABLE 5. ANOVA results of risk perception scales. Two asterisks indicated significance at $p < 0.05$.

Scale		Sum of squares	F
Climate change local global risk	Between groups	10.77	3.62**
	Within groups	1147.60	
	Total	1158.33	
Climate change extreme events	Between groups	3.99	1.50
	Within groups	1008.46	
	Total	1012.46	

TABLE 6. Post hoc Tukey honestly significant difference (HSD) test for climate change local to global risk scale (subset for $\alpha < 0.05$; means for groups in homogenous subsets).

	Sample group	<i>N</i>	1	2
Tukey HSD	Denver	252	3.54	3.54
	Las Vegas	220		3.60
	Phoenix	304	3.33	
	Significance		0.14	0.81

Table 2). Gender had a weak negative effect on overall risk perception (males had lower risk perception) but did not predict personal risk perception. Similarly, pro-environmental worldview and perceived personal responsibility were the strongest predictors of risk perception related to extreme weather events. Procedural knowledge related to water management also weakly negatively predicted risk perceptions of extreme weather events, indicating people with more procedural knowledge believed that their city would experience fewer negative impacts from extreme weather events. Trust in government was not a significant predictor in any of our models.

4. Discussion

Our results indicate that risk perceptions may be increasing in Denver, Las Vegas, and Phoenix, but there are several reasons this should be cautiously interpreted. As the survey we administered focused on questions about respondents' perception of the need for water management changes, the people who completed our survey may have been motivated to complete it precisely because they perceived a need for water management changes (i.e., self-selection bias; Whitehead 1991). The framing of the overall survey may have primed people to consider whether sociotechnical changes were needed in the face of environmental changes, influencing how people responded to questions on climate change risk perception. We carefully designed our survey to minimize these issues, but nonetheless such issues cannot be eliminated and it is important to consider the impact of the survey context on responses. Additionally, our questions were adapted from Howe et al. (2015) and are not identical. Our survey was phrased to assess respondents' certainty associated with negative climate

change impacts ("how certain"), while Howe et al. (2015) asked about the magnitude of harm ("how much"). Both questions examine underlying constructs tied to risk perceptions, but these subtle differences limit direct comparisons. Our survey also employed the phrase "climate change," while Howe et al. (2015) used "global warming"; these phrases are likely to be interpreted differently among respondents (Whitmarsh 2009). While potentially rising risk perceptions in Denver, Las Vegas, and Phoenix are an intriguing initial result, for the above reasons further research is needed to support the conclusion that the gap in climate change risk perception between the public and experts is indeed decreasing at subnational levels.

We found small differences in climate change risk perception across our three metropolitan areas (Table 5), indicating that similar adaptation strategies modified to fit local contexts may be supported by the public across these major metropolitan areas. If policymakers from city, state, and other scales engage in collaborative social learning that is an opportunity of polycentric climate governance, insights garnered about generic adaptation strategies may be altered to fit city-specific social-ecological risks and resources (Pelling et al. 2008).

Practical implications of our findings

In contrast to our hypothesis, trust in government was not a significant predictor of risk perception. We hypothesize that the unique and changing political circumstances in the United States at the time of survey administration (early 2018) may have influenced the high levels of distrust reported by respondents and the relationship between risk perception and government (Table 12). In our models, the two primary drivers of risk perceptions were pro-environmental worldview and perceived personal responsibility.

These results have several implications relevant to efforts to address climate change initiated by decision-makers in Denver, Las Vegas, Phoenix, and other similar cities. Although risk perception influences whether people engage with climate change adaptation and mitigation, Weber (2010) suggests that decision-makers should be cautious about attempting to increase public risk perception. This caution is related to cognitive limitations, including people's finite capacity for concern or worry (i.e., when people are worried about climate

TABLE 7. Model comparisons for climate change local to global risk.

Model	<i>R</i>	<i>R</i> ²	Adjusted <i>R</i> ²	Std error
1: Constant and NEP	0.73	0.53	0.53	0.84
2: Constant, NEP, and personal responsibility	0.75	0.56	0.55	0.82
3: Constant, NEP, personal responsibility, and gender	0.75	0.56	0.56	0.81
4: Constant, NEP, personal responsibility, gender, and procedural knowledge	0.75	0.56	0.56	0.81

TABLE 8. Model-4 results for climate change local to global risk. Two asterisks indicate significance at $p < 0.05$; three asterisks indicate significance at $p < 0.0001$.

	Unstandardized B	Std error	Standardized beta	t
Constant	-0.62	0.17		-3.69
NEP scale	0.93	0.04	0.68***	26.07
Perceived personal responsibility	0.24	0.04	0.18***	6.32
Gender	-0.16	0.06	-0.07**	-2.57
Procedural knowledge	-0.07	0.03	-0.06**	-2.13

change, they are less worried about other issues) and single-action bias (people's tendency to take one action to reduce risk without evaluating its effectiveness) (Weber 2010). There are several opportunities for decision-makers to influence factors that may increase public engagement with adaptation and mitigation efforts, while minimizing unintended consequences associated with intentionally increasing risk perception.

Institutional changes of laws, policies, and social norms are some of the most onerous social changes to achieve, but they are likely to have the most enduring impacts on climate change adaptation and mitigation (Ostrom 2012). Approaches focused on influencing, motivating, or creating new institutions can encourage people to overcome single-action bias through social learning and ignite social responsibility to address anthropogenic climate change (Caney 2005; Weber 2010). Institutional change to address climate change risks could take diverse forms, but institutions that connect multiple issues (like climate change and air pollution) may increase public buy-in (e.g., Hölscher et al. 2019). As cities increasingly assume the burden of climate change adaptation, policymakers and practitioners can look to examples from cities experimenting with public-private partnerships (e.g., Rotterdam and New York City; Hölscher et al. 2019; Sarzynski 2015). Public engagement with creating new institutions helps establish inclusive and legitimate institutions (Finkbeiner et al. 2018; Nursey-Bray et al. 2017).

Considering that risk perception is often a precursor to people participating in collective action (Etkin and Ho 2007), the potential increase in people that believe climate change is personally risky measured by our survey could also indicate an increase in the number of people willing to participate in local efforts to address

climate change. If risk perceptions in Denver, Las Vegas, and Phoenix are increasing, what do our results indicate decision-makers and communities can do to encourage and facilitate collective action among those who understand climate risks? Self-efficacy (the belief of individuals that they are capable of conducting an action or creating change) and collective efficacy (the belief that a group is capable of achieving shared goals) are important drivers of collective action (Roser-Renouf et al. 2014). Americans' efficacy related to climate change has been declining, while risk perceptions have increased (Leiserowitz et al. 2017). This indicates an area of opportunity for climate change decision-makers and communicators because people with high risk perception but low levels of perceived efficacy are no more likely to participate in collective action to address climate change than people who do not believe climate change is occurring (Roser-Renouf et al. 2014).

To encourage collective action as public risk perception increases, decision-makers should focus on efforts to grow efficacy, as well as the two most influential drivers of risk perception in our models (environmental worldviews and personal responsibility). Factors that influence pro-environmental worldviews interact and mediate each other in complex ways (Gifford and Nilsson 2014), so attempts to alter environmental worldviews are not straightforward. However, focusing on efforts to increase personal responsibility for the environment may also help to foster environmentally responsible behavior (Story and Forsyth 2008). Environmental education initiatives (e.g., related to urban gardens) that resulted in increased self-efficacy have also increased perceived personal responsibility for the environment (Johnson et al. 2007). Further, presenting information on solutions first, followed by relevant

TABLE 9. Model comparisons for climate change extreme events.

Model	R	R^2	Adjusted R^2	Std error
1: Constant and NEP	0.68	0.47	0.47	0.83
2: Constant, NEP, and personal responsibility	0.70	0.50	0.49	0.81
3: Constant, NEP, personal responsibility, and procedural knowledge	0.71	0.51	0.51	0.80
4: Constant, NEP, personal responsibility, procedural knowledge, and gender	0.72	0.51	0.51	0.80

TABLE 10. Model-4 results for climate change extreme events. Two asterisks indicate significance at $p < 0.05$; three asterisks indicate significance at $p < 0.0001$.

	Unstandardized <i>B</i>	Std error	Standardized beta	<i>t</i>
Constant	-0.07	0.17		-0.43
NEP scale	0.80	0.04	0.62***	22.45
Perceived personal responsibility	0.26	0.04	0.21***	7.06
Procedural knowledge	-0.12	0.03	-0.10***	-3.59
Gender	-0.19	0.06	-0.08**	-2.99

information on risks (Roser-Renouf et al. 2014) and using images related to positive imagined futures (on climate-related topics like energy) in climate change communications (O'Neill et al. 2013) will aid in building self-efficacy. In dry, western U.S. metropolitan areas, initiatives to engage the public in imagining positive futures under increased drought combined with information on solutions to local projected climate impacts may aid in increasing efficacy and fostering a sense of personal responsibility for the environment. There is a need for more empirical research on 1) efforts to improve self- and collective efficacy related to climate change, particularly the relationship between drivers of risk perceptions such as pro-environmental worldviews and personal responsibility, and 2) whether any measured improvements in efficacy resulted in increased collective action related to climate change. Any initiatives by decision-makers to increase efficacy also present an opportunity for scientists to advance our understanding of related collective action outcomes.

Researchers require more locally specific information about social norms surrounding the public's participation in climate change collective action to support endeavors to address climate change. For example, we need to understand perceptions of expected participation and personal responsibility, efficacy, and actual participation rates of broader actions like contacting elected officials, attending climate change-related public meetings or rallies, and supporting organizations that work on climate change issues. There is a growing body

of research on social norms surrounding household practices like water conservation (e.g., Larson and Brumand 2014; Schultz et al. 2016). Human risk perceptions and behaviors are influenced by those within their social groups (Creutzig et al. 2018). Thus, researchers have increasingly noted that new institutions that address social norms may result in larger-scale changes capable of crossing tipping points (Creutzig et al. 2018; Nyborg et al. 2016). For instance, climate policies that directly engage with local social norms (e.g., those surrounding consumption of fossil fuels via driving) may catalyze widespread behavioral changes. In cases where behaviors are visible, providing "reasons for people to believe that others will take up less damaging behaviors" may encourage large-scale change in social norms (Nyborg et al. 2016). One option is via policy changes that provide incentives for beneficial adaptations and encourage the development of pro-environmental worldviews and personal responsibility.

Our results directly indicate that in Denver, Las Vegas, and Phoenix efforts by decision-makers to provide the public with information on how they can be involved with water-related decision-making are welcome (Table 12). We used water-related decision-making as a proxy for climate-related decision-making relevant across these dry, western U.S. metropolitan areas. In this case, procedural knowledge may be an indirect barrier to addressing climate change risks. Procedural knowledge had a weak negative effect on overall risk perception in our model, but because the effect of procedural knowledge was small, it does not appear to be an important driver of risk perception. Other research has shown that people with greater risk perceptions are less likely to implement adaptation strategies if they lack access to information about the strategies available and how to implement them (Sousa-Silva et al. 2018). Thus, we pose that the gap between people in Denver, Las Vegas, and Phoenix interested in participating in water decision-making and the knowledge about how to do so is an opportunity for decision-makers. In particular, city governments and local nongovernment organizations can establish or strengthen outreach initiatives to connect the public with information on how they can be involved in shaping water policies and

TABLE 11. Binary logistic regression results for perception of climate change as personally risky. Two asterisks indicate significance at $p < 0.05$; three asterisks indicate significance at $p < 0.0001$.

	<i>B</i>	Std error	Wald	Odds ratio
Constant	-19.51	11.18	3.05	0.00
NEP scale	2.08***	0.17	157.58	8.04
Procedural knowledge	-0.12	0.12	0.96	0.89
Personal responsibility	0.60***	0.13	22.51	1.83
Trust in government	0.13	0.14	0.86	1.14
Gender	-0.02	0.20	0.01	0.98
Race/ethnicity	0.40	0.23	3.05	1.50
Education	-0.107**	0.054	3.88	0.90

TABLE 12. Respondents' support for water decision-making, procedural knowledge, and trust in government (percent of respondents).

		Denver	Las Vegas	Phoenix
Thinking about water management for your town or city, to what extent would you support or oppose residents, such as yourself, working with local water managers to make decisions?	Strongly oppose	0.5	2.2	3.1
	Somewhat oppose	1.5	1.3	3.5
	Neutral	25.9	21.0	26.5
	Somewhat support	35.1	38.5	35.6
	Strongly support	37.0	36.9	31.2
How much would you say you know about how to participate in water resource decision making for your community?	Nothing at all	42.2	28.3	46.4
	A little	27.3	28.7	29.4
	Some	20.1	26.1	17.1
	Quite a bit	5.0	9.5	5.4
	A great deal	5.3	7.5	1.8
In your opinion, how often can the federal government in Washington D.C. be trusted to do what is right?	Never	12.3	7.8	16.9
	Rarely	43.6	38.7	33.8
	Sometimes	35.7	38.8	43.7
	Very often	5.4	11.3	5.6
	Extremely often	3.1	3.5	0
In your opinion, how often can your town or city government be trusted to do what is right?	Never	3.0	3.9	7.1
	Rarely	15.5	14.9	21.7
	Sometimes	50.8	60.1	54.3
	Very often	26.2	14.1	13.8
	Extremely often	4.5	7.1	3.1

practices, and how water governance in these cities is directly connected to climate change.

Our survey asked respondents to consider climate change risks on a scale relevant to societal transitions, contemplating changes over the next 30 years. Transitions within many social-ecological systems will be necessary to achieve sustainability as systems confront climate change risks. The implications discussed here can be designed and implemented as part of a managed transition, as institutional-based approaches are an integral part of transitions (Loorbach et al. 2017). Efforts by practitioners to transform the institutions that shape public engagement with risk perception and adaptation efforts could be framed as part of broader transition efforts (Wise et al. 2014). New institutions should incorporate long-term goals, incorporate cross-scale and cross-sector solutions, and encourage experimentation and learning (Hölscher et al. 2019). Historical analyses can help researchers, policymakers, and others to influence ongoing transitions by understanding what catalyzed past efforts to change institutions. For instance, transformational changes in water-related institutions in the U.S. West and Southwest were often preceded by periods of political or social crisis, leading to the insight that future periods of disorder represent windows of opportunity to change existing institutions (Sullivan et al. 2017).

5. Conclusions

Government officials, practitioners, and scientists working to engage the public in climate change related issues

will benefit from an increased understanding of local patterns and drivers of public risk perception. We found that the percentage of people in three metropolitan areas in the western United States (Denver, Las Vegas, and Phoenix) that believe climate change is personally risky was greater than results of previous studies, indicating perceptions may be shifting. To take advantage of potentially increasing risk perceptions, and encourage collective action, decision-makers should focus on increasing efficacy. However, even if our findings are replicated in the future, this still portends much of the general public in the metropolitan areas of three large U.S. cities does not view climate change as personally risky. Weber (2010) notes that a failure to recognize the risks posed by climate change is a despairingly self-corrective issue—eventually, as people experience detrimental effects of climate change, risk perception will inevitably increase. The primary drivers of risk perception in our models were pro-environmental worldview and perceived personal responsibility. Focusing on developing initiatives to increase climate change collective action that emphasize solutions and invoke drivers of risk perception, like fostering pro-environmental worldviews and a greater sense of personal responsibility, is a promising avenue to increase engagement in adaptation and mitigation efforts—before the majority of the public acquires personal experience with detrimental effects of climate change.

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