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A perspective for identifying intersections among the social, engineering, and geosciences to address water crises

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Reliable access to safe water is essential for health, wellbeing, and the livelihoods of people. However, water security innovations benefit when engineering and geoscience decisions consider systemic human, social, and organizational realities, needs, and goals. Indeed, true innovation that leads to water security requires intensively inclusive and iterative processes to occur at multiple scales of analysis across diverse sciences—for this, expertise and knowledge across the varied sciences is essential to facilitate such convergent, transdisciplinary research. Here, we articulate our perspective for identifying points of intersection and working across disciplinary boundaries to address water crises. Our perspective takes a multidimensional view of community, organization, family, and individual resilience in the face of natural and human hazards. It builds upon previous models of cumulative water related risk by nuancing the relationships amongst levels of analysis, and expanding the idea of cumulative impacts to include interactive impacts (e.g., buffering, enhancing, effects and other moderators), mediated effects (i.e., mechanisms of impact), as well as additive and suppressive linkages amongst risk and protective factors.

KEYWORDS

water, crises, contextual, resilience, integrative, natural hazards, disasters, traumatic

Introduction

Natural and human hazards as well as climate change present a concerning threat to water security, causing a multitude of water crises across the world and these are only projected to increase (Young et al., 2019; He et al., 2021). Advancing water security and justice in communities around the world involves tackling the grand challenges of water security and providing universal access to clean water. This involves empowering communities to become sustainable, resilient, and adaptive while recognizing geophysical, engineering, and human challenges and differences across myriad landscapes, infrastructure, social and political realities (Callejas Moncaleano et al., 2021). Thus, while reliable access to safe water is essential for health, wellbeing, and the livelihoods of people, innovations for water security cannot happen with engineering and geoscience decisions made without the systemic social and organizational realities, needs, and goals in mind (Mukherjee J. et al., 2022; Mukherjee S. et al., 2022).

In fact, recent water insecurity challenges and crises, such as those in cities such as Flint, MI and Jackson, MS (Seeger and McElmurry, 2023) as well as those resulting from natural hazards, are arguably products of limited decision making that did not sufficiently account for the complex human and built systems involved (Martin-Ortega, 2023). Indeed, true innovation that leads to water security requires intensively inclusive and iterative processes to occur at multiple scales of analysis—for this to happen, expertise and knowledge across the varied sciences is essential to facilitate such convergent research (Mukherjee J. et al., 2022; Mukherjee S. et al., 2022). Here, we articulate our perspective for working across disciplinary boundaries to address water crises as developmental psychologist (CW), humanitarian engineer, (CP) and environmental engineer (KI).

Traditionally, water management and decision-making are an "engineering problem," but water related crises have led to a growing recognition of the need to broadly systemic solutions (Contzen et al., 2023; Martin-Ortega, 2023). Communities across the world, particularly marginalized ones, experience physical and psychological health water related risks including water scarcity, water contamination, unreliable water service, and mistrust in public water (Kim et al., 2023). Black, Hispanic, Indigenous, and rural communities are particularly vulnerable to water insecurity due to historic political and ecological injustices (Mueller and Gasteyer, 2023). Addressing these issues effectively is crucial for communities to remain sustainable, resilient, and healthy; such efforts require transformative approaches in which there are a true convergence of expertise and actions, not just varied sciences working in isolation or parallel on the same problems.

Research that transcends traditional units of analysis is needed (Ovink et al., 2023). In order for true convergence, there is a need for "transdisciplinary" research programs to move the water crisis science to sustainable action but also in doing so create new perspectives. Interdisciplinary research emphasizes the integration of perspectives, concepts, and methods from different disciplines. Drawing from Pohl (2011), transdisciplinary work seeks to extend the different approaches to generate new frameworks, and methods that "transcend" the disciplinary bounds. This also involves direct collaborations with and involvement of non-academic partners in scholarship and evaluation to ensure that the concepts and methods have utility in real-world settings and real world needs drive the research agenda to create better approaches (Pohl, 2011; Weems et al., 2021).

Our perspective

We start by clarifying our goal in this paper and a working definition of theory, model and data drawn from Wunsch (1994). Theories as plausible explanatory propositions devised to link possible causes to their effects. Theories are typically field or domain specific. Models are schematic representations constructed to improve understanding about the world and/or to make predictions. Models are intermediate between theory and data and data in science involves empirical observations used to confirm or falsify theories and models. Our perspective for integration across water sciences begins with the idea that water insecurity is a systemic problem that can best be addressed through multiscale, multi-level innovation in science and policy. As a beginning a schematic model of points of possible intersection across multiple contexts may facilitate bringing multiple perspectives to bear. This is because the hazards that lead to water crises involve acute natural forces/disasters, climate change induced crises, but also political, community, and individual actions, across community and human lifespans. The hazards can involve too much water in flooding, too little water in drought or bad water in contamination. Our perspective uses a broadly contextual model of community, organization, family, and individual resilience in the face of natural and human water hazards and crises to identify points of intersection between the social sciences, engineering and the geosciences.

The overall schematic model is outlined in Figure 1A and is broadly consistent with the U.S. Environmental Protection Agency (EPA) cumulative impacts model highlighting the combined influences of the built, natural, and social environment for individuals, communities, or population groups (U.S. EPA, 2022 and the initial conceptual scheme from Tulve et al., 2016). However, our model builds upon the previous realizations in EPA and other emerging work (see e.g., Mukherjee and Bhattacharya, 2023) by nuancing the relationships amongst levels of analysis. Our model expands the idea of cumulative impacts to include interactive impacts (e.g., buffering, enhancing, effects and other moderators), mediated effects (i.e., mechanisms of impact), as well as additive and suppressive linkages amongst risk and protective factors. The model also implies multiple avenues of intersection via developmental theories of the acquisition behavioral reactions, attitudes, and emotions. Ultimately, the theories and modes of knowledge in different fields may represent a complementarity (see Weems, 1999) as opposed to a true integration but may eventually lead to new modes of knowing.

Figure 1 is an extension of a human development bio-ecological systems model applied to water crisis resilience and provides an overview of various ecologies that may influence community, organization, family, and individual water crisis resilience and how they may be interrelated with each other to foster resilience (adapted from Weems, 2019). Recognizing and understanding the embedded inter-connections across multiple levels of analysis allows for a comprehensive assessment of risk and resilience by identifying the moderators and mediators of hazard impacts on water (Arrows in Figure 1A). We focus on the term resilience or the capacity to bounce back after crises given our work in disasters which are inherently associated with risk, which recognizing the distinction between fostering resilience, preventing water crises and generally fostering human wellbeing (see United Nations Office for Disaster Risk Reduction, 2015; Weems et al., 2018; Mukherjee and Bhattacharya, 2023). This provides several points of possible intersection with examples in Table 1.

The perspective expands previous models by fostering the integration of theories in social science such as psychology, anthropology, political science, sociology, and economics, in engineering, and basic science in geosciences and beyond. Preparedness planning and disaster response that targets connections crossing the ecologies may help augment traditional targets for prevention and risk mitigation in the face of water

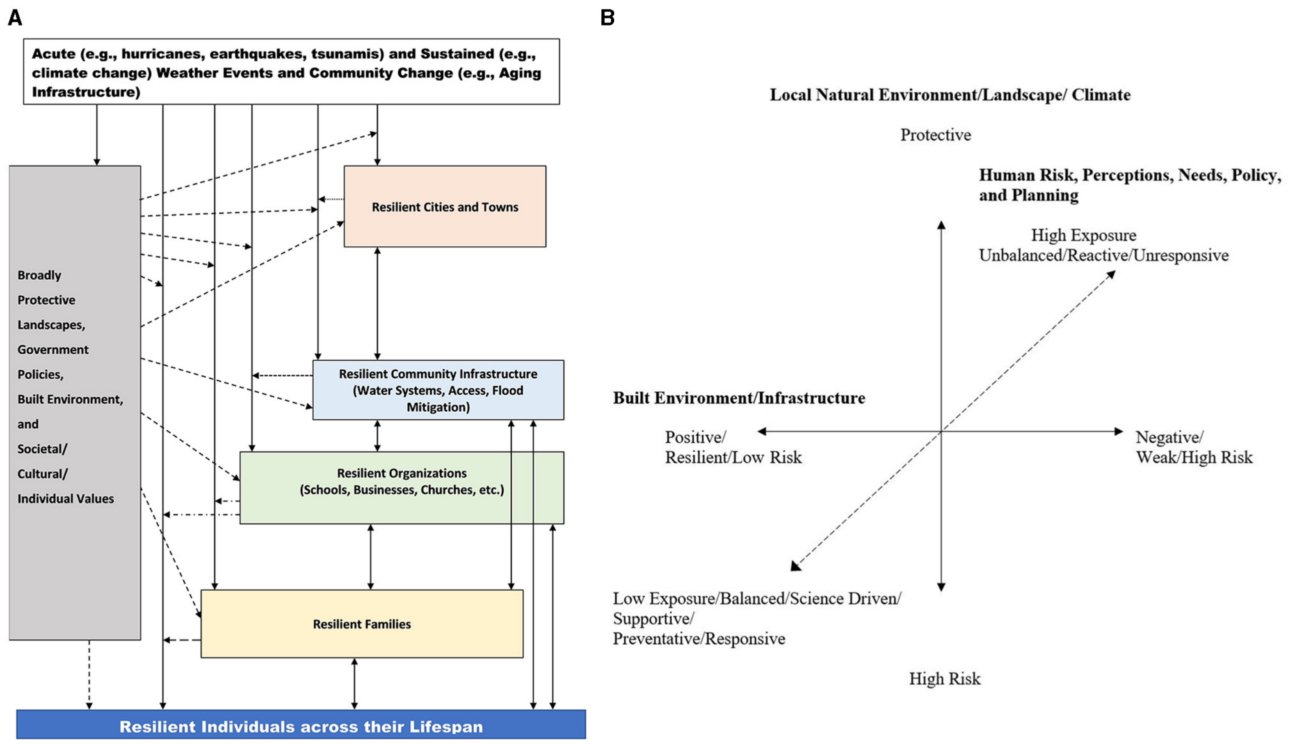

FIGURE 1
A schematic model of community, organization, family and individual resilience to foster positive human development with engineering, geoscience, and social science intersections on water crises. **(A)** Illustrates an overview of various contexts and factors that may influence community, organization, family, and individual water crisis resilience and how they may be interrelated with each other to foster resilience (Adapted from Weems, 2019). Recognizing and understanding the embedded inter-connections across multiple levels of analysis allows for a comprehensive assessment of risk and resilience by identifying the moderators and mediators of hazard impacts on water [Arrows in **(A)**]. **(B)** The x-axis represents the built environment and community resources from positive and resilient (e.g., wealthy community, well-built structures and water management systems) to negative and weak (e.g., poor marginalized community and systems). The y-axis represents the natural environment from protective environments with adequate water access or protective soil geographical environments to high-risk environments such as naturally dry or disaster prone geographical locations. The z-axis represents several human element factors such as water needs, political and community responsiveness to science, prevention, and investment from balanced, science driven and supportive preventative and responsive to unbalanced and unresponsive.

crises. The multiscale approach of our model considers multiple actors and social processes that determine and are impacted by water insecurity including community, organization, family, and individual scales their nested interrelations and also unique mechanisms of action. Recognizing the complexities of balancing natural and human systems (see Cinner et al., 2020, 2022), our perspective seeks to find points of convergence across levels of analysis. The models is based on well-established contextual models of lifespan human development (e.g., Bronfenbrenner, 1979) of risk and resilience to stress (e.g., Hobfoll, 1989; Sandler, 2001) and newer models of human resilience in the face of severe stress (Weems and Overstreet, 2008; Bonanno et al., 2010; Weems et al., 2021). The field of disaster response broadly has increasingly emphasized the importance of identifying resilient subsamples in trauma and disaster exposed individuals (Bonanno et al., 2010; Weems et al., 2021). The model extends this understanding of individual human resilience by looking to the engineering and geosciences in terms of the built and natural environment around resilient cities, resilient landscapes, resilient community infrastructure, as well as socially around resilient organizations and families.

The perspective uses Bronfenbrenner's ecological systems approach, which posits that individuals function within multiple contexts, or "ecologies," that influence each other and human development (Bronfenbrenner, 1979; Hobfoll, 1989; Sandler, 2001; Weems and Overstreet, 2008; Weems, 2019). The ecologies in the traditional ecological system model include the macrosystem, which is the most distal ecology and includes the government and culture, including cultural values and beliefs. The exosystem consists of processes taking place between two or more contexts with implications for the individual (e.g., community; parents, spouse, workplace). The mesosystem represents the linkages between proximal ecologies (e.g., connections between work/school and home) and the microsystem represents the proximal ecologies within which an individual develops, including the family and work/school environments and social/peer relationships. The ontogenic level is the ecology of the individual and represents factors within the individual that influence developmental adaptation. These traditional ecologies can be simplified to (1) broad context like nation or state government, (2) local community/organization, (3) family and (4) individual. Emerging data shows the linkage of water crises to the individual

TABLE 1 **Points of intersection between physical sciences and social sciences across contexts and systems.**

Ecology and relation to model (Figure 1) components	Examples of natural and built environment (engineering and geosciences) and social, behavioral and economic risk or resilience promoting factors and their connections across boundaries	
Macrosystem- broadly protective landscapes, government policies, cultural values and beliefs	Identifying specific built or natural environmental risk combined with a high resources and culture of social action mitigates risk	
	Physical	Geographic location and physical geography may be protective thereby reducing risk or confer risk via a variety of physical or geographical characteristics
	Social	Socio-economic status; cultural values of support foster social relatedness thereby increasing levels of social support for those affected or produce change
Exosystem- processes taking place between two or more broad contexts/ecologies	Active organizations mobilize political action to improve water systems or increase conservation efforts	
	Physical	Geographical water access and built systems management/infrastructure
	Social	Community variation in social organizations that take action on policies and community efforts
Mesosystem- linkages between proximal ecologies	Educational opportunities to learn about Community water systems and their access to natural resources; community historical exposure to toxins	
	Physical	Community water systems and their access to natural resources; community historical exposure to toxins
	Social	Variation in educational systems and access to information
Microsystem- the ecologies within which lower levels of model components exist	Family wealth buffers against exposure to toxins	
	Physical	Variation in household water use and access; household water systems, home infrastructure
	Social	Family resources, family stress, family political culture
Ontogenic - the individual	Exposure to TRACEs exacerbates exposure to water related toxins	
	Physical	Individual exposure to water related toxins
	Social	Traumatic and adverse experiences (TRACEs); individual wellbeing and perceptions of water quality; changes in human stress response systems

via these broader contexts (e.g., school absence; Kim et al., 2023).

Table 1 outlines the levels of analysis across potential research areas implied by the perspective with example targets of study and theoretical expertise across various disciplines. The perspective posits that acute (e.g., hurricanes, earthquakes, tsunamis) and sustained (e.g., climate) weather events as well as political and community conflict (e.g., aging infrastructure, lack of public trust) represent potential main effect insults to community, organization, family, and child wellbeing (i.e., arrows pointing from the top box). However, communities, organizations, families, and individuals are nested within each other (i.e., the double-headed arrows between ecologies) and so higher levels in the model are part of the mechanism whereby disasters and water crises exert their influence. Table 1 shows areas of possible intersection in expertise, concepts, and methods across disciplines and levels of analysis drawing from the engineering and geosciences to examine resilience promoting factors across disciplines to address and mitigate water crises. In the following, we expand on the examples in Table 1 and implications of the perspective in Figure 1A.

From Figure 1A, protective landscapes and governmental policies represent the broadest level of water crisis buffering/resilience fostering (Mueller and Gasteyer, 2023). These may include geographic characteristics, broad government policies, national infrastructure, cultural values as well as regional and national norms particularly with respect to social justice and underserved communities (Bobo, 2006; Mueller and Gasteyer, 2023). In particular, national infrastructure and wealth including socioeconomic and demographic characteristics are related to disaster-related deaths and injuries (Haque, 2003) and national wealth is related to less damage and death following a disaster (Toya and Skidmore, 2007). At the Community level (involving macro, eco and mesosystems in the model), different communities adapt and mitigate water insecurity differently through social capital, public trust in water infrastructure, policy, local government management, and community decisions and actions. At the organization level, this level of analysis focuses on decision making processes in governance such as water laws and policies, as well as engineering. This identifies prevention and policy work targets as well as innovations needed in both general and specific education and workforce development for those who work specifically or broadly in water decision making. These broadest level targets are in line with the Priority 3 of the United Nations Sendai Framework for disaster risk reduction Investing in disaster risk reduction for resilience and Priority 4 enhancing disaster preparedness for effective response, and to build back better in recovery, rehabilitation and reconstruction (United Nations Office for Disaster Risk Reduction, 2015).

The family and individual levels (microsystems and ontogenetic levels) involves examining factors within the individual and within families that influence developmental adaptation. For example, at the individual level, direct exposure to threat increases activity of the limbic-hypothalamic-pituitary-adrenal axis as part of a normative fight-flight reaction. Intense taxing of this system may lead to dysregulation of the system and has been associated with poor emotion regulation and behavioral problems across development. For example, exposure to Traumatic and Adverse Childhood Experiences (TRACEs, Weems et al., 2021) are associated with differential health and mental health outcomes as well as differential physical development such as brain development. These have differentially effected families from underserved communities leading to higher rates of justice and foster care system involvement. Water access and quality perceptions are also linked to health and mental health outcomes (Nelson T. et al., 2023; Nelson T. N. et al., 2023).

Convergence across levels and disciplines

In addition to cumulative effects across levels of analysis, our model predicts important interdependencies. Communities, organizations, families, and individuals are nested within each other (see Figure 1A). This nesting implies that resilience in each of the upper levels will foster resilience in lower levels in complex ways. This idea of complexity within and across levels is visually depicted in Figure 1B. Figure 1B, helps to specify the nature of and thereby identify susceptibility to negative water related outcomes. The x-axis represents the built environment and community resources from positive and resilient (e.g., wealthy community, well-built structures and water management systems) to negative and weak (e.g., poor marginalized community and systems). Existing data has shown the linkages between water violations, air and water quality, and community/individual level health indicators (Tulve et al., 2016; U.S. EPA, 2022). The y-axis represents the natural environment from protective environments with adequate water access, soil properties or other protective soil geographical environments to high-risk environments such as naturally dry or disaster prone geographical locations. Again existing data shows linkages between geographical indicators and health outcomes (Tulve et al., 2016; U.S. EPA, 2022). The z-axis represents several human element factors such as water needs, political and community responsiveness to science, prevention, investment from balanced, science driven and supportive preventative and responsive to unbalanced and unresponsive. Here again, individual level risks such as water quality and access perceptions, exposure to traumatic and adverse childhood experiences, link to both community individual health and mental health outcomes (Young et al., 2019; Weems et al., 2021; Nelson T. et al., 2023; Nelson T. N. et al., 2023).

Communities in the lower left hand quadrant are at lowest risk and represent model communities for understanding prevention and resilience to water crises. Communities in the upper right hand quadrant are at high risk. Individuals in the middle of the lower left hand octants are at lowest risk and represent individuals who should be less likely to experience water crises. Individuals in the upper right hand octants are at high risk. Communities in the lower left hand quadrant are at lowest risk and represent model communities for understanding resilience to water crises. Communities in the upper right hand quadrant are at high risk. Individuals in the middle of the lower left hand octants are at lowest risk and represent individuals who should be less likely to experience water related impacts and crises. Individuals in the upper right hand octants are at high risk. However, individuals who are doing well in these octants actually represent resilient individuals.

To explain, a critical feature in the accurate empirical identification of resilient communities, individuals, and families is the level of risk exposure an individual, family or community who is doing well experiences – just doing well with no or low risk exposure is not true resilience it's simply non-exposed to risk. Diverse definitions of resilience exist across disciplines with perspectives that go beyond simple bounce back adaptation to highlight transformation (see Schlüter et al., 2019). In our work we have emphasized a definition of resilience that emphasizes both the simplicity and subtlety with which the concept can be considered. Resilience refers to the idea that some facing adversity nonetheless do well or return to positive functioning following a period of maladaption (Sroufe, 1997). Resilience then is critically defined by (1) exposure to some risk (e.g., facing disaster related adversity/community exposure) as well as (2) the relatively positive functioning of some individuals compared to others. The relative positive functioning may involve bouncing back but may also involve adaptive transformations consistent with (Schlüter et al., 2019). However, it is also critical as a subcomponent of point 1 that the "resilient" have the same level of risk exposure as the non-resilient. Risk has been defined as "characteristics of the person or the environment that are associated with the increased probability of maladaptive developmental outcomes" (Compas et al., 1995, p. 273; for related discussion of resilience in the disaster sphere see Sendai Framework, United Nations Office for Disaster Risk Reduction, 2015).

Community level exposure in the lower left hand quadrant represent risk- however within those communities there will be resilient individuals and families – knowing their characteristics represent model individuals for understanding individual resilience to water crises. For example, individual education, income, and low exposure to adverse childhood experiences (Weems et al., 2021) may be a protective factor for individuals in such communities protecting them from the adverse effects of the risk conveyed by their community. Similarly, there may be communities that have high geological risk but are non-the-less doing well – again the built environment or characteristics of the community members and organizations within the community may protect these particular communities from water crises.

Our perspective also capitalizes on well-established mechanisms of human development and mechanisms of environmental risk to wellbeing with biological, behavioral and social/interpersonal causal factors functioning to explain risk and resilience across levels in the model. Behavioral conceptualizations of human reactions to threat propose respondent (classical or Pavlovian conditioning), vicarious (social modeling), and operant

(Skinnerian conditioning) mechanisms of the acquisition of fear. Limitations of early classical conditioning accounts involving the direct pairing of stimuli with aversive events (e.g., a dog bites you resulting in fear of dogs) have suggested multiple learning pathways (Bouton et al., 2001). One pathway is through classical aversive conditioning (Wolpe and Rachman, 1960). A large body of research suggests that exposure to traumatic events is associated with increased risk for emotional disorders, particularly posttraumatic stress disorder (PTSD; indeed, the diagnostic criteria for PTSD mandate exposure to life-threatening trauma). Exposure to natural disasters, such as floods and hurricanes, is also associated with anxiety, depression and PTSD symptoms (Weems et al., 2007, 2021). The second pathway is vicarious acquisition through observational learning or modeling. Via this pathway, individuals may acquire behavioral reactions, attitudes, or emotions such as fear or distrust by observing the actions of salient others such as parents, caregivers, siblings, or friends (Bandura, 1982). For example, a child who sees his or her mother or father react negatively to a tap water may begin to model this reaction. The third pathway is through verbal transmission of information. Through this mechanism, individuals may acquire behavioral reactions, attitudes, or emotions by talking about fearful things with parents, caregivers, siblings, community members or friends. For example, the type of information (positive vs. negative) one receives about water issues in one's community (e.g., contamination, flooding) can change the valence of beliefs (Field, 2006).

Social and interpersonal theories focus on relationships with others. Moreover, social contextual approaches suggest that factors such as poverty, parental psychopathology, exposure to TRACEs can exacerbate vulnerability. According to attachment theory, for example, a child's interactions with the environment are influenced by the underlying quality of the parent-child relationship, and a number of factors influence the quality of that relationship (e.g., poverty, parental psychopathology). Attachment theory suggests that human infants form enduring emotional bonds with their caretakers (Bowlby, 1977). When the child's caretakers are responsive, the resultant emotional bonds can provide a lasting sense of security that continues even when the caretaker is not present. However, an inconsistently responsive caretaker, a neglectful caretaker, or some other disruption in the parent-child bond may be associated with insecure attachment. Similarly, a sense of community, family, or individual security is therefore theoretically fostered by responsive community government and emergency management systems. Indeed research suggests that perceptions of the actual water system may influence attitudes with aging infrastructure fostering concern (Nartey et al., 2024) with the model implying effects through observational learning about the built environment compounded by a sense of a lack of security.

Discussion

Successful integration of diverse disciplinary components and working in diverse communities requires a broad perspective that can create a collaborative culture. As previously noted, different sciences often base their perspectives on different knowledge paradigms, which can pose challenges for integrative work (Wesselink et al., 2017; Mukherjee J. et al., 2022; Mukherjee S. et al., 2022). A culture of collaborative work de-emphasizes a hierarchy of actors, emphasizes the importance of the parts (people/perspectives) to the whole (project/goal), and foster a pluralistic understanding and knowledge base (see Evers et al., 2017). Foundationally, to cultivate a collaborative culture, we will create space and time to address the challenges of fragmented disciplinary language and paradigms (Bammer, 2003; Max-Neef, 2005). We seek to actively address a central challenge in transdisciplinary work – overcoming syntactic boundaries such as differences in terminology and paradigms across fields (examples from Table 1). Public, academic, and community entities working to provide water security are heterogeneous. These entities focus on diverse aspects of water insecurity while historically have been considered at odds can be complementary (see Rusca and Di Baldassarre, 2019). Stakeholders of this work are defined broadly as private groups, advocacy groups, public agencies, community groups and individuals. The perspective emphasizes a community of practice (Wegner, 2011) a community-based participatory research approach. Such work typically has at least three objectives: (1) introduce the academic and non-academic representatives, (2) learn from the non-academic partners about what they currently have in operation related to water insecurity and where they see gaps in services in this point in time, and (3) build the institutional capacity for water security through enhanced collaboration.

Closing examples with initial empirical support helps to illustrate the above perspective. Exposure to environmental toxins, have cumulative life course affects (Tulve et al., 2016). Similarity exposure to TRACEs have cumulative effects of the life course with evidence of a dose response for the cumulative effects of both on both physical development and mental health (Weems et al., 2021). However, together there may be interactive effects where TRACEs interact with exposure to environmental toxins. Indeed, there is evidence to suggest that exposure to lead increases stress responsivity and that combined exposure to stress and lead leads to effects on development in the absence of either alone (Cory-Slechta et al., 2008).

Similarly, certain human factors such as perceptions of water quality and distrust of water or community water systems likely have complex relationships (implied by Figure 1B) with the built environment, the natural environment, exposure to toxins (for additional empirical example see Daniel et al., 2021). For example, mistrust in communities with safe municipal water supply can lead to the use of sources, which may be more expensive and unnecessary (bottled), or in fact, may be more toxic (taking untreated water from streams or other natural but untreated/tested sources Nelson T. et al., 2023; Nelson T. N. et al., 2023). On the other hand, mistrust when there are true water problems can lead to individual and community action to protect individuals or change community infrastructure to address the issue. The destruction wrought by Hurricane Maria in 2017 left the island's infrastructure, including its water systems, severely damaged (Michaud and Kates, 2017; Laskow, 2018; Ballesteros et al., 2023). Since then, Puerto Ricans have frequently faced water shortages and disruptions (Preston et al., 2020). In the immediate aftermath of Hurricane Maria, more than half the population, approximately 1.5 million people, were left without access to potable water (Joseph et al., 2020). In 2017 Puerto Rico had the most severe drinking water violations of any US state or territory, with approximately 99.5% of the population consuming water from systems that violated the Safe Drinking Water Act in 2015 (Fedinick et al., 2017).

Research from our team shows related shifts in tap water drinking behavior with the individuals mistrusting the public water supply and shifting to consuming bottled water (Nelson T. N. et al., 2023). Similarly, water insecurity issues have contributed to diverse mental health consequences such as depression and lower perceptions of psychological resilience and that there are individuals and communities where there are disjunctions between perceptions of water quality and actual water quality (Nelson T. et al., 2023). This data is providing initial evidence for the predictions in Figure 1. Specifically, the built environment, the natural environment, and previous exposure compounding mistrust in communities with safe municipal water supply leading to the use of sources, which may be more expensive (bottled), or may be more toxic (taking untreated water from streams or other natural but untreated/tested sources).

As a final example, compelling data suggests that community racial/ethnic composition predicts drinking water quality, but also that socioeconomic factors moderate (interact with racial/ethnic composition) the effect of with black and Hispanic communities most strongly predicting water violations in low socioeconomic communities (see Switzer and Teodoro, 2018). Water insecurity is also a significant problem in Alaska Native communities (Taylor et al., 2022, 2023). Over 3,300 rural Alaska homes and approximately 3% of Alaskan residents lack access to piped water and flush toilets (Alaska Department of Environmental Conservation, 2023). In addition, aging water infrastructure and climate change are leading to the infrastructure damage resulting in frequent water service disruptions and recurring water quality problems (Spearing et al., 2022). One significant concern is the potential presence of contaminants, including heavy metals and persistent organic pollutants due to both natural processes and human activities (Muller and Matz, 2002). Research from our team in these communities show that the people mistrust the water utilities and systems (Nartey et al., 2024) which is not surprising given recurring water shortages, contamination issues, pump failure, or freezing pipes in its water tank extended boil water notices (Alaska Department of Environmental Conservation, 2023). Again, these findings are consistent with the broader model where the natural environment compounds infrastructure issues leading to community level distrust and potentially water related economic, physical and psychological stress.

Data availability statement

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

Author contributions

CW: Conceptualization, Writing—original draft, Writing—review & editing, Funding acquisition, Project administration, Visualization. CP: Conceptualization, Funding acquisition, Writing—original draft, Writing—review & editing, Project administration. KI: Conceptualization, Funding acquisition, Writing—original draft, Writing—review & editing, Project administration.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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