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Participatory approaches in water research: A review

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Abstract

Participatory research approaches address a range of problems in water research, including the under-valuation of local knowledge, exclusion of marginalized people, preferential treatment of elite and expert perspectives, and extractive and exploitative research practices. Beyond this, a number of participatory approaches to water research are designed to empower participants, democratize knowledge production, improve decision-making, and help bring about new environmental futures. In this primer, we map participatory research approaches and explain how they have been applied to advance water research. Our review focuses on the following eight approaches: participatory action research, community-based participatory research, participatory rural appraisal, stakeholder research, participatory modeling, photovoice, citizen science, and sustainable future scenarios. We conclude by discussing a new approach, Participatory Convergence research, including how it builds from other approaches and its prospects to advance water research.

This article is categorized under:

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KEYWORDS

community engagement, participatory convergence, participatory research, stakeholder research, water research

1 | INTRODUCTION

Participatory research represents a school of thought with a range of methodologies and research designs grounded in ideas of social justice, knowledge democratization and acknowledging that research participants are more than research subjects and they should plan an active role in part (and in occasions all) components of the research process. Along with the recognition of social equity and empowerment, participatory research challenges traditional research approaches that represent research "on" or "about" instead of "with" individuals and communities (Macaulay, 2017). Participatory research approaches serve multiple purposes (from consultation to action), and participants' degree of participation varies (see Cargo & Mercer, 2008; Petras and Porpora, 1993; Reed, 2008). Nonetheless, all participatory research approaches recognize participants as co-producers of knowledge (Bergold & Thomas, 2012); often aligned with a goal for education or transformative action and guided by principles of research to advance social or economic justice, challenge unequal power relations, and promote reflexivity and other iterative, self-informing research processes (Bergold & Thomas, 2012; Cargo & Mercer, 2008).

In water research, participatory approaches have been used in various disciplines from social science, health sciences, engineering to natural sciences. In this review, we discuss a range of participatory approaches deployed in water research while examining questions about power, control, and choices in the involvement of participants in the research process (Cornwall & Jewkes, 1995). Given the increasing acknowledgment that participatory approaches can confirm relevancy or research objectives, potential for empowerment to address public challenges and their opportunity to increase implementation of research findings, they are increasingly adopted by water scholars for disciplinary, interdisciplinary, and transdisciplinary work (Grassini, 2018; Irvin & Stansbury, 2004; van Buuren et al., 2019). At the same time, involvement of participants in scientific research has been recognized to provide unique opportunities to engage in knowledge co-production and changing the way in which science informs pathways of action and decision making (Lane et al., 2011). Our review considers the underpinning rationale of each identified method with a focus on how approaches address (a) how decision-making across projects is relatively researcher versus participant-driven and, (b) the extent to which the broader research process itself aims to inform (as per traditional scientific research) versus motivate change (see Figure 1). These distinctions are driven by how the participatory approach was conceptualized (including at what stage of the research process the participant plays an active role) and review of the application of these approaches in water research. In participant driven approaches, research participants inform earlier stages of the research such as the research objective. In contrast, research driven approaches refer to participant's active role in later stages of the research such as in the data collection and dissemination. Information orientation refers to the outputs of the research are mainly targeted to report without anticipation of action. However, action orientation denotes research findings are expected to be use for further activity. Nonetheless, we acknowledge that these approaches can change in practice given research objectives, local histories, and the ideologies of the stakeholders involved (Wallerstein et al., 2017). These approaches can be used in combination to advance a research agenda. For each participatory approach, we consider the theoretical and practical rationales underpinning its basic design, disciplinary orientation,

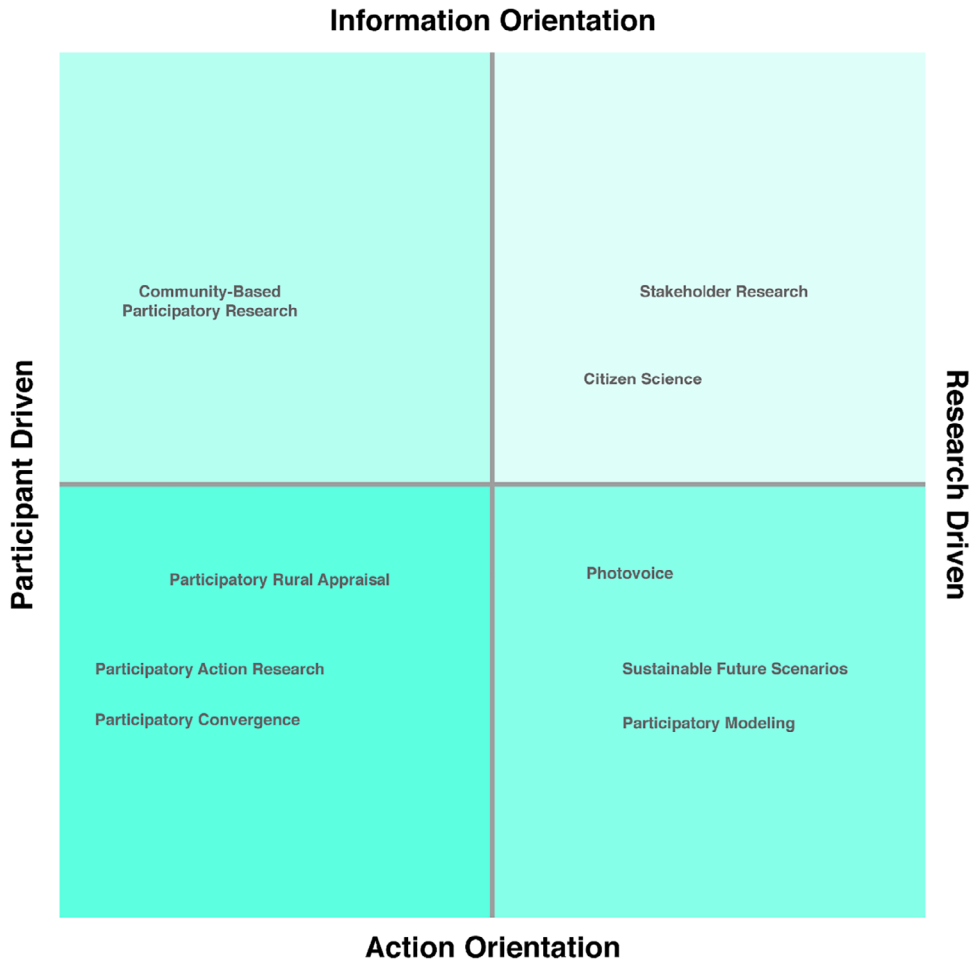

FIGURE 1 A framework for differentiating participatory approaches commonly applied in water research

participant's role in the research process, benefits, challenges, and applications in water research. As shown in our diagram, our framework is meant to be illustrative of a range of approaches, rather than comprehensive or prescriptive.

We based the framework on the conventional use of the method and applications in water research, but these are not statics and while some work uses them traditionally others have used them in combination or with a more equity lens incorporating participants in earlier stages of the research process.

2 | RESEARCHER-DRIVEN APPROACHES TO INFORMING PARTICIPANTS ABOUT WATER

2.1 | Citizen science

Citizen science is a participatory approach designed to democratize the research process, and to increase public involvement in and understanding of science (Bonney et al., 2009; Irwin, 2002). In its 150-year history (Dickinson et al., 2010), citizen science has been used in disciplinary, interdisciplinary, and transdisciplinary research with most applications in the ecological and biophysical sciences, including conservation, hydrology, and water resources research (Kobori et al., 2016; Njue et al., 2019; Paul et al., 2018), rather than the social sciences (Richardson, 2016). Some social scientific approaches, such as citizen sociolinguistics (SturtzSreetharan, 2020), have developed rapidly in the last 5 years, and research suggests that citizen social sciences could play a key role in addressing the human dimensions of water, including improving public participation in water and climate policy (Kythreotis et al., 2019).

In citizen science, typically, untrained volunteers ("citizen scientists") access and document observations that otherwise would not be able to do by a single researcher or small research team and report them to study directors (Kobori et al., 2016). In water research, citizen scientists can play a crucial role in public science communication, including raising public awareness and acting as bridges between scientists and local communities to address watershed management and other water challenges (Bonney et al., 2014; Church et al., 2019; Tipaldo & Allamano, 2017). Citizen scientists can also support implementing projects where there is limited funding, but a large dataset or sample size is needed (Rae et al., 2019). Water researchers generally ask citizen scientists to observe water quality (e.g., pathogens, turbidity), river flow, rainfall, flooding, pollution, soil moisture, vegetation, and biodiversity (Buytaert et al., 2014, Dickinson et al., 2010, Paul et al., 2018). The OPAL Water Survey, for instance, used citizen science to access the ecological status of 78 urban drainage ponds in Scotland by observing invertebrates (Rae et al., 2019). As part of their findings, they reported the value of citizen science by allowing a range of actors from children to families to engage in this process without formal ecological background and reflected on implications for science education.

While there is a range of benefits from citizen science, from increasing science education to support in data collection, some critiques argue that complex protocols, constant data submission, and inconvenient locations are barriers to successful citizen science projects (Kobori et al., 2016). Ethical concerns have also been raised with citizen scientists regarding labor, compensation of their work, reciprocity of benefits, and cultural sensitivity (Chesser et al., 2020; Rasmussen & Cooper, 2019). Moreover, others have argued that the promise of science democratization is often unfulfilled (Walker et al., 2021), especially when citizen scientists are seen merely as a free source of labor and their involvement is limited to observation (Silvertown, 2009). To address this, some water studies involve citizen scientists in the complete research process, ending with participatory modeling or scenario building to interpret results in a collaborative way (Buytaert et al., 2014).

2.2 | Stakeholder research

Stakeholder engagement is a participatory design that seeks to address the complexity of human-environmental relationships by embracing "a diversity of knowledge and values" for environmental decision making (Reed, 2008, p. 2417). Drawing from organizational and environmental management literature, stakeholder engagement research has increased since the 1990's aimed to challenge traditional top-down approaches to address water resource management and water governance (Akhmouch & Clavreul, 2016; Conallin et al., 2017). In the last three decades, stakeholder engagement has been embraced in water resource management for capacity building in decision making, reducing

technocratic approaches, developing solutions to address water challenges, social justice, and enhance fairness, among others (Conallin et al., 2017; Conley & Moote, 2003; Lauer et al., 2018).

When possible, stakeholder participation is considered at the beginning of the research process and throughout (Conallin et al., 2017; Reed, 2008). Conventionally, however, stakeholders are involved in the implementation of the research and the evaluation of findings rather than in deciding research objectives and preparation (Estrella et al., 2000; Reed, 2008). Stakeholder research is increasingly seen as a viable approach to creating socio-environmental change in water management due to opportunities for social learning and consensus-building among different stakeholder groups (Conallin et al., 2017; Eaton et al., 2021; Reed et al., 2018; Wehn et al., 2018). For example, a case study of stakeholder engagement in the Willamette Basin, Oregon (Ferguson et al., 2017) reports on the experiences of participants in a "researcher-stakeholder engagement process" to address collaborative decision-making about future water scarcity and use. The case study identified that, while motivations and expectations varied among stakeholders, they were active collaborators in data interpretation and decision-making, benefiting collaborative research and knowledge co-creation.

As discussed by Carr's (2015) review on stakeholder and public participation in river basin management, participation of stakeholders is projected to bring three important elements: (1) opportunity for better quality decisions (from which "better" responds to sustainability development, social equity, and related areas), (2) interactions for human and social capital to mobilize and support implementation, and (3) legitimizing decisions to support implementations (p. 395). However, one challenge to conducting stakeholder engagement research is that stakeholders can change over the course of a project, as people move or start new employment that changes their role (Prell et al., 2021). Other challenges include conflicts between interest groups, power imbalance and the cost-effectiveness of the project (e.g., cost of the project vs. outputs in decision making) (Carr, 2015).

3 | RESEARCHER-DRIVEN APPROACHES TO TAKING ACTION ON WATER

3.1 | Photovoice

Photovoice is an increasingly popular participatory method since the late 1990's which asks participants to capture key themes in photos, collaborative analyze and discuss them, and communicate themes back to their community (Fantini, 2017; Wang & Burris, 1997). Photovoice meets many of the philosophical aims of participatory methods, including democracy and centering local needs and concerns. Drawing from critical consciousness, feminist theory, and participatory documentary photography; photovoice is a methodology with three main goals: (1) to facilitate through pictures the recording and reflection on a community's challenges and assets; (2) to guide a critical discussion and collective knowledge production; and (3) to support action by reaching policymakers (Wang & Burris, 1997).

In photovoice, participants play an active role in taking pictures based on a research team photo prompt, then, using focus groups or interviews, participants elaborate on and analyze these images' emotions, values, and meanings. Finally, events such as exhibitions allow such reflections to reach policymakers and participants involved in selecting images for this event (Baldwin & Chandler, 2010; Latz et al., 2016; Mitchell, 2018). Increasingly, water scholars have used photovoice to evaluate water and health, sanitation, hygiene, water governance, watershed management, and water resources (Baldwin & Chandler, 2010; Bisung et al., 2015; Fantini, 2017; Pereira et al., 2005; Radonic & Jacob, 2021), with largely positive outcomes reported. One example of this is Mitchell's (2018) work with tribal members of the American Indian community in the midwestern United States. Her work utilized photovoice within an environmental justice framework to study how environmental change in water affected health and well-being. After identifying themes such as significance of the river, causes of water insecurities, and water usage adaptations, the findings of this work were used to support local efforts in their legal and political activities (e.g., tribal reports) for water security in their community.

Utilizing visual methodologies such as photovoice has received recognition for its opportunity to expand understanding of everyday water challenges. For example, Fantini (2017) review of photovoice and similar visual methodologies (e.g., photo novella) for water governance, found that this methodology not only facilitates thinking about water concerns, but also explore its multidimensional perspectives and raise awareness about these everyday experiences with water. Similarly, visual methodologies such as photovoice provide a bridge for new relationships (e.g., researchers and participants, among participants; participants with policy makers) (Fantini, 2017; Keremane & McKay, 2012). Challenges encountered with this method in water however include community dynamics that impede focus groups from

discussing images and length of different project stages (Mitchell, 2018). Another challenge is having a positivist perspective on the images and disregarding the social and cultural construction of the photos (Chew et al., 2019).

3.2 | Sustainable future scenarios

Sustainable future scenarios (SFS) are a participatory methodology that builds on earlier concepts of "scenarios." Scenarios are future narratives designed to produce anticipatory knowledge (Millennium Ecosystem Assessment, 2005) and have been recognized as a methodology to support socio-environmental decision-making and policy (Elsawah et al., 2020). Scenarios were introduced in the 1940s for security analysis (Berkhout & Hertin, 2002) and strategic decision-making (Shell, 2005). Recently SFS was established to encourage the co-development of positive, long-term alternative future visions with a focus on urban sustainability and resilience (D. M. Iwaniec et al., 2020).

In the SFS framework, research participants in collaboration frame the issue, identify strategies, define and explore scenarios (D. Iwaniec & Wiek, 2014; Iwaniec et al., 2020; Berbés-Blázquez, 2021). Scenarios have been applied to a range of water problems: water sustainability, water use, water products and services, water management, and water policy (Henriques et al., 2015; Gielczewski et al., 2011). For example, researchers have mapped water futures up to 2060 for Phoenix, Arizona using SFS and WaterSim6, a water modeling tool (Sampson et al., 2020). Findings from this work showed that scenario co-creation extended the capacity to explore urban development and water demands and encourage informed discussions among stakeholders on the future of water. Similarly, scenario analysis served as a baseline for decision-makers to create policies that can be flexible under the different scenarios while educating on the value of foresight to address environmental challenges in a desert city (Sampson et al., 2020).

As water insecurity has become a global challenge, researchers are turning to future scenarios to address uncertainties (e.g., Proskuryakova et al., 2018, Keeler et al., 2015). SFS however, is particularly useful for exploring outcomes under uncertain conditions with a focus on sustainability and resilience (Sampson et al., 2020; Iwaniec et al., 2020). Additionally, it balances desirability against plausibility to guide decision-making while incorporating diverse perspectives in the co-production of positive future visions (Iwaniec et al., 2020). Challenges by those using scenario analysis nonetheless include difficulty in conveying the complexities of the scenario into a coherent narrative, consistent and active participation of all stakeholders invited into the project, and attention to who is involved in the scenario development to address challenges of inclusion (Kowalski et al., 2009; Nilsson et al., 2021; Elsawah et al., 2020).

3.3 | Participatory modeling

Participatory modeling is a cooperative, collaborative modeling method. It evolved in the 1990s from environmental scientists' recognition of the value for community input in planning and policymaking, particularly in watershed contexts and environmental management through modeling processes like group model building and companion modeling (Hubacek et al., 2017; Quimby & Beresford, 2023). Participatory modeling moves from traditional modeling by fostering interdisciplinary and transdisciplinary and enabling participatory processes in research by bringing scientists and nonscientists together to support environmental decision-making (Landström et al., 2011; Landström et al., 2019; van Eeten et al., 2002). In participatory modeling, usually, participants are involved mainly in a series of workshops with researchers where they develop a shared model to visualize how environmental and hydrological processes work and decide on potential policies or management actions (Gray et al., 2018; King & Thornton, 2016; Sterling et al., 2019; Voinov & Gaddis, 2008).

Participatory modeling provides a unique method for bringing forth diverse perspectives, particularly from "nonexpert" community members, through the use of graphic media to visualize and communicate dynamic, multiscale processes (Nyaki et al., 2014). For example, Gaddis et al. (2010) detail the process for participatory modeling in a Vermont watershed, from identifying and recruiting participants, setting an agenda for the group, and developing a model to address stream pollution and stormwater management from agricultural and residential communities. Collaborative development of the model helped participants move beyond historical conflicts and blame to developing new understandings of watershed complexity and finding acceptable solutions.

Benefits from participatory modeling include building trust and cooperation between researchers and communities by reducing power asymmetries between experts and nonexperts and allowing researchers to examine how power relations and participants' perspectives and relationships shift over time with engagement (Butler & Adamowski, 2015;

Kimmich et al., 2019). It can also bring forward local knowledge, values, social learning, and worldviews, as participants work together to identify what elements to include in the model (d'Aquino & Bah, 2013; Hubacek et al., 2017). However, this process can also present challenges. Water scholars have identified that computer modeling applications, such as virtual environments and geographic information systems (GIS), provide the easiest way to integrate different types of environmental data. However, this technology can be complicated for participants to access (Evers et al., 2012). Providing time and training, or using analog processes (blackboard, paper, etc.) for developing their shared vision, are important considerations.

4 | PARTICIPANT-DRIVEN APPROACHES TO BUILDING WATER KNOWLEDGE WITH PARTICIPANTS

4.1 | Community-based participatory research

Community-based participatory research, or CBPR, is a research design particularly adopted by health researchers since late 1990's. CBPR has been informed by emancipatory social theory and poststructuralism, emphasizing the process of aligning researchers and community agenda by valuing, and investing in community collaboration and knowledge democratization (Wallerstein & Duran, 2010; Wallerstein et al., 2017). CBPR tends to focus on identifying community priorities or concerns around the research process. The goal is to co-create knowledge and enact an iterative collaborative research process—so the community transforms the research, and the research transforms the community's knowledge. Hence, in CBPR, participants define research objectives, data collection, data analysis, and dissemination of research findings. CBPR is often focused on designing iterative and ongoing projects for the co-creation of knowledge and research. It can be done without an explicit emphasis on social change, and often aims to maximize community engagement, participation, capacitation (e.g., teaching research skills) and leadership (e.g., community advisory or oversight boards). For example, Cartwright and Schow (2016) describe a CBPR water project in rural Peru where the CBPR elements included working with the community to focus on water quality as the central concern (although the project itself was then implemented through more traditional research techniques).

Most water-related works labeled explicitly as CBPR is concerned with environmental management and water quality as a health threat to reduce health disparities (e.g., Cummins et al., 2010, Balazs & Morello-Frosch, 2013; Wehn & Almomani, 2019). The literature on CBPR has also produced detailed and explicit discussions about costs and benefits to communities and researchers. For example, projects led by community concerns (e.g., water quality over fair distribution) may shift focus away from scientific evidence and toward research designs based on untested/untestable assumptions. They can also shift focus to problems that may not be solvable given the research team, time, and resources available. CBPR can center community gatekeepers or facilitators in ways that reinforce inequalities related to local power structures within the community, benefitting some at the cost to others (e.g., Guta et al., 2013). Also, community engagement poses a time burden to those who act as advisors or leaders. In lower-income and marginalized communities, the burden of even a small amount of time to those working and raising families can be substantial (Wood & Kallestrup, 2021). This is not to say such issues are not manageable, but that they require time, resources, foresight, creativity, commitment, and (sometimes vast) amounts of built trust to navigate.

5 | PARTICIPANT-DRIVEN APPROACHES TO TAKING TRANSFORMATIVE ACTION ON WATER

5.1 | Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) is a research design that "describes a growing family of approaches and methodologies to enable local people to share, enhance, and analyze their knowledge of life and conditions to plan and act" (Chambers, 1994, p. 1). It is multidisciplinary in nature and was initially primarily used by nongovernmental organizations and international development organizations to collaborate with rural communities. PRA was developed in the late 1970s drawing from community development and international development literature seeking to include locals to evaluate, analyze, and make informed decisions to better their own communities' conditions through projects challenging traditional ways of data collection and supporting local community development plans (Alam & Ihsan, 2012;

Chambers, 1992; Chandra, 2010). PRA aims to address two key concerns in rural social research, inadequately fulfilled via traditional methods. First, PRA identifies local perceptions through more feedback from local people and conditions. Second, PRA is a method to acquire timely and cost-effective information.

In PRA traditionally, participants are involved in the "development of plans and activities," analysis, and any plans following research findings (Chambers, 1992, p. 8; Sadanandan et al., 2007). Scholars have used PRA in diverse fields of water research such as water resources management, watershed planning, and management, groundwater management, drinking water, and sanitation (Belay et al., 2013; Khair et al., 2021). For instance, Al-Qubatee et al. (2017) used the PRA technique in groundwater research in Coastal Yemen. They examined the causes of groundwater degradation and its mitigation strategies. By applying PRA techniques such as key informant interviews and group discussions and grounded in a process to co-analyze their findings, villagers were able to analyze the cause of the problems and suggest suitable measures for alleviating the water problems. This study concluded that PRA tools are practical and valuable for dealing with data insufficiency and cultural diversity. While PRA has many benefits for research with rural people, other scholars identify significant difficulties in PRA, including the cultural differences, inequalities in power and control, potential to stir up conflicts, time/money, and proper knowledge/skills for communication and facilitation (Chambers, 1994; Leurs, 1996).

5.2 | Participatory action research

With roots in social psychology, liberationist ideology, and the action research paradigm more broadly, participatory action research (PAR) is a research design that looks to center marginalized or underserved populations in research. In PAR, participants become co-researcher and engage all stages of research through cycles of inquiry, action, and reflection with an express purpose of effecting change (Kemmis & McTaggart, 2007). Emerging in the 1960's challenging positivism and the role participants should play in the research process, including their benefits to participate; PAR seeks to go beyond specific methods to create research-participant partnerships to address social change. In essence, researchers that engage with PAR are aware of political forces and oppressive systems and thus involved in this approach to uplift local knowledge, values, and empowerment of all members involved and with the goal of actionable outcomes and learning (Lammerink, 1998).

In PAR, following the "spiral" metaphor participants are involved in all the stages of the research process from research objectives to using research findings to plan for action (Kidd & Kral, 2005). Water researchers have used PAR for to study indigenous water reserves, rural water supply management, water resource conservation, water planning, community sanitation, hygiene, and safe drinking water. For example, Nikolakis and Quentin Grafton (2014) conducted PAR research with Indigenous groups in the Northern Territory of Australia. Their work included developing a supportive framework for fairness in restorative water allocations for Indigenous groups. As part of this framework, researchers and their indigenous collaborators identified dynamics in negotiation, indigenous objectives for just or fairwater allocations, and signal procedural errors in the past for water allocation. Their PAR approach consisted of political and social learning, coordination and validity of research design and workshops, data collection with partners, and constant reflection of their project. As part of their key findings, authors describe that PAR benefited groups with

BOX 1 CBPR and PAR: similarities and differences in water research

In much community-centered research, CBPR and PAR are terms that are sometimes used interchangeably. CBPR is occasionally described as a form of PAR. Both approaches share a commitment to maximizing community engagement and benefits at all stages of the research process—planning, execution, and dissemination. And both require moving beyond simply collaborating with a community in the process of obtaining research approvals to collect data or having community-members help collect data or provide it as participants. Yet we can identify useful distinctions between PAR and CBPR relevant to how solution-focused water research is conducted. PAR is based in theories of change and emphasizes the imperative of action to that end. CBPR may not always be goal-oriented toward action but can be about building trust or shared values between researchers and research communities.

different goals to reach consensus, explore values and past experiences as well as to a ground for discussions to provide water justice to these groups.

PAR is the approach most often adopted for researchers committed to participant-driven transformative change. Some of the disadvantages identified from water research experiences with PAR include planning time frames, alignment of political context, time length, resource expenses, negatively impact local conflicts, and difficult-to-navigate power relations (Ferreyra, 2006; Mackenzie et al., 2012; Rammelt, 2014; Box 1).

5.3 | Participatory convergence

Recent research has drawn attention the need for an approach that merges the advantages of participatory action and transdisciplinary research to address growing global water challenges (Krueger et al., 2016; Workman et al., 2021). Participatory convergence research, a relatively new approach, is designed to meet these challenges. Convergence is a transdisciplinary research approach refined over three decades, building from nanotechnology, health sciences, and science and technology studies (Bainbridge & Roco, 2015). More recently, scholars in climate change and disaster science incorporate community and stakeholder participation in convergence research. Drawing from this recent research, we identify the emerging approach of participatory convergence (Birthisel et al., 2020; Lakhina et al., 2021; Bainbridge & Roco, 2015; Westerhoff et al., 2021).

TABLE 1 Overview of participatory approaches

Participatory approach	Objective of the approach	Expected outcomes
Participatory action research	Center marginalized voices in the research process (McTaggart, 1991).	Action plan from marginalized groups (McTaggart, 1991).
Community based participatory research	Partnership with local communities to address health challenges (Wallenstein & Duran, 2010).	Collaboration to promote health in communities (Wallenstein & Duran, 2010).
Photovoice	Give agency to participants using a camera or pictures (Fantini, 2017; Wang & Burris, 1997).	To inform policy or decision-making (Fantini, 2017; Wang & Burris, 1997).
Citizen science	Increase public participation in natural resources challenges through monitoring sites for ecological research (Dickson et al., 2010; Irwin, 2002).	Data to inform the public (e.g., education) or decision makers on natural resource management (Dickson et al., 2010; Irwin, 2002).
Stakeholder research	Engage diverse people who have a "stake" on a particular environmental management challenge for decision-making (Eaton et al., 2021; Reed, 2008).	Social learning and consensus building among different stakeholder groups for decision-making (Eaton et al., 2021; Reed, 2008).
Participatory rural appraisal	Give rural people agency in the research process (including viable for action) in collaborations with agencies and researchers (Belay et al., 2013; Chambers, 1994).	Center participants in research about their own community including education and opportunity to plan for action (Belay et al., 2013; Chambers, 1994).
Participatory modeling	Bring diverse stakeholders from community members to decision makers to provide insights, address the tradeoffs, and come to consensus on a model for a natural resources challenge (Nyaki et al., 2014; Voinov & Gaddis, 2008).	Model that considers diverse perspectives in a particular natural resource management challenge (van Eeten et al., 2002; Voinov & Gaddis, 2008).
Sustainable future scenarios	Framework to co-develop positive futures considering sustainability and resilience (Iwaniec et al., 2020; Sampson et al., 2020).	Future scenarios inclusive of sustainability and resilience (Iwaniec et al., 2020; Sampson et al., 2020).
Participatory convergence	Bring a diverse team of researchers and centering community needs as part of the research process (Birthisel et al., 2020; Lakhina et al., 2021).	Transformational plausible solutions for complex problems (Birthisel et al., 2020; Lakhina et al., 2021).

In participatory convergence, a diverse team develops transformative solutions to complex problems through intensive integration across disciplines, communities, and organizations (Birthisel et al., 2020; Peek et al., 2020). Participatory convergence, like PAR, seeks an active engagement of participants as collaborators in the research process, interpreting and sharing findings, and supporting change (Birthisel et al., 2020; Lakhina et al., 2021). For example, in Lakhina et al.' (2021) disaster research in New South Wales, Australia proposes a convergence ethics based on "converging with CARE—collaboration, accountability, responsiveness, and empowerment" when discussing participant integration in their research project (Lakhina, 2019; Lakhina et al., 2021, p. 301). Converging with CARE requires a willingness to disregard top-down approaches and have deep engagement with community partners including their perspectives, questions, and experiences (Lakhina et al., 2021).

Participatory convergence is a promising mode of inquiry to address anthropogenic climate change challenges. Early findings indicate a need for more explicit techniques for funding, planning, and incorporating participation at every stage of convergence research (Birthisel et al., 2020; Westerhoff et al., 2021). In coming years, more research is needed to establish the efficacy of participatory convergence in supporting meaningful water research and plausible water solutions in the anthropogenic climate change context. Table 1. Provides an overview of the discussed approaches.

6 | DISCUSSION

Participatory approaches share a collective value that bringing participants into the full research process improves both the research and the applications of the research. Engaging in participatory research in water has shown to bring numerous benefits, including but not limited to giving agency to local people in scientific production, democratizing science, diversity, and representation of perspectives, opportunities for action planning, evaluation, and education (Radonic & Jacob, 2021; Ricaurte et al., 2014; van Buuren et al., 2019). As we have outlined here, a range of practical factors—including time constraints, funding, research objectives, researcher and participants ideologies, socio-cultural factors, and the project timeline determines the nature of participation in water research. Ideally, such constraints are balanced iteratively as part of an effort to redress and share power. At the same time, the decision to use a participatory research design or method in water research is guided by a commitment to knowledge democratization and the added value that the participatory approach would bring to researchers and those directly impacted by the phenomenon studied. Characteristics that seem to determine the success of participatory approaches in water research include investments in building trusting relationships, diversity in perspectives and respect for those, tangible benefits to all partners, local leadership in defining appropriate methodologies, setting expectations, acknowledging that it takes time, and active input.

Participatory approaches in water can be difficult, slow, expensive, and otherwise burdensome for researchers and participants/communities alike. For example, many research teams lack the time, funding, and capacity building needed for meaningful full integration of participants in the research process unless this is an explicit part of proposals that translates to funded budgets; this also requires those funding research to value the investment. In addition, the iterative process and nonresearcher control that defines many participatory projects raises concerns with scientific rigor. However, there are techniques to address some if not all of these concerns, such as triangulation and detailed documentation of the different stages of the research process (Cornwall & Jewkes, 1995). Despite the challenges in water research, participatory approaches offer an unmatched opportunity to engage communities and stakeholders to seek meaningful and sustainable solutions.

In reviewing these eight approaches we highlight the added value for water research. For example, PAR and CBPR, are research designs that share a partnership approach with participants to address a water challenge and where their input shapes all stages of the research process. Photovoice and citizen science give participants agency to document water challenges impacting them with the potentials to influence policy and decision-making arenas. PRA and stakeholder research can foster important evaluation by those directly impacted or in power to enact change to water challenges in their communities or institutions. In turn, participatory modeling, and sustainable future scenarios, are methodologies that bring opportunities to embrace diversity of perspectives and for different views to provide input and find consensus on solutions-orientated products for water futures. Moreover, participatory convergence brings an outstanding opportunity to advance water research's technological, ecological, and social dimensions while increasing plausible and evident-based sustainable solutions. As we have organized these methodologies and research designs in our framework focusing on how traditionally they have brought research participants in the different stages of the research process, we recognize in practice this will be shaped by a range of factors including research objectives,

funding, and time. Participatory research can foster critical evaluation by those directly impacted or in power to enact change to water challenges in their communities or institutions. These methodologies give participants agency to document water challenges impacting them and potentially influence policy and decision-making arenas. They elevate participant's knowledge and experiences with the ultimate goal of advancing complex problems with plausible and evident-based sustainable solutions. While we have presented participatory research in a simple framework with clear examples, we also note that it is a diverse, experimental, and constantly evolving field. It promises to continue to innovate in ways potentially relevant to the entire water research effort.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

AUTHOR CONTRIBUTIONS

Anais Roque: Conceptualization (lead); writing – original draft (lead); writing – review and editing (lead). **Amber Wutich:** Conceptualization (lead); writing – original draft (lead); writing – review and editing (lead). **Barbara Quimby:** Writing – original draft (equal); writing – review and editing (equal). **Sarah Porter:** Writing – original draft (equal); writing – review and editing (equal). **Madeleine Zheng:** Writing – original draft (equal); writing – review and editing (equal). **Mohammed J. Hossain:** Writing – original draft (equal); writing – review and editing (equal). **Alexandra Brewis:** Conceptualization (supporting); writing – original draft (equal); writing – review and editing (lead).

DATA AVAILABILITY STATEMENT

Data sharing does not apply to this article as no new data was created or analyzed in this work.

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FURTHER READING

Barrington, D. J., Sridharan, S., Saunders, S. G., Souter, R. T., Bartram, J., Shields, K. F., Meo, S., Kearton, A., & Hughes, R. K. (2016). Improving community health through marketing exchanges: A participatory action research study on water, sanitation, and hygiene in three Melanesian countries. *Social Science & Medicine*, *171*, 84–93. https://doi.org/10.1016/j.socscimed.2016.11.003

Borda, O. F., Reason, P., & Bradbury, H. (2006). Participatory (action) research in social theory: Origins and challenges. In *Handbook of action research* (pp. 27–37). London: SAGE Publications.

Bradford, L. E. A., Zagozewski, R., & Bharadwaj, L. A. (2017). Perspectives of water and health using photovoice with youths living on reserve. *The Canadian Geographer*, *61*(2), 178–195. https://doi.org/10.1111/cag.12331

Brooks, S. J., Fitch, B., Davy-Bowker, J., & Codesal, S. A. (2019). Anglers' Riverfly Monitoring Initiative (ARMI): A UK-wide citizen science project for water quality assessment. *Freshwater Science*, *38*(2), 270–280.

Brouwer, S., Van der Wielen, P. W., Schriks, M., Claassen, M., & Frijns, J. (2018). Public participation in science: The future and value of citizen science in the drinking water research. *Water*, *10*(3), 284.

Gonzalez, P. A., Zarger, R. K., Ann Vitous, C., & Prouty, C. (2019). Understanding children's perspectives on water resources in interdisciplinary research. *Practicing Anthropology*, *41*(1), 32–37.

Hargrove, W. L., & Heyman, J. M. (2020). A comprehensive process for stakeholder identification and engagement in addressing wicked water resources problems. *Land (Basel)*, *9*(4), 119. https://doi.org/10.3390/land9040119

Jollymore, A., Haines, M. J., Satterfield, T., & Johnson, M. S. (2017). Citizen science for water quality monitoring: Data implications of citizen perspectives. *Journal of Environmental Management*, *200*, 456–467.

Maclean, K., & Woodward, E. (2013). Photovoice evaluated: An appropriate visual methodology for aboriginal water resource research. *Geographical Research*, *51*(1), 94–105. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1745-5871.2012.00782.x

Mendoza, G. A., & Prabhu, R. (2006). Participatory modeling and analysis for sustainable forest management: Overview of soft system dynamics models and applications. *Forest Policy and Economics*, *9*(2), 179–196.

Morinville, C., & Harris, L. M. (2014). Participation, politics, and panaceas: Exploring the possibilities and limits of participatory urban water governance in Accra, Ghana. *Ecology and Society*, *19*(3), 1–12.

Mott Lacroix, E. K., & Megdal, B. S. (2016). Explore, synthesize, and repeat: Unraveling complex water management issues through the stakeholder engagement wheel. *Water*, *8*(4), 1–16. https://doi.org/10.3390/w8040118

Mukherjee, N. (1997). *Participatory rural appraisal* (Vol. 1). Concept Publishing Company.

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, *19*(3), 354–365.

Pearson, L. J., Coggan, A., Proctor, W., & Smith, T. F. (2009). A sustainable decision support framework for urban water management. *Water Resources Management*, *24*(2), 363–376. https://doi.org/10.1007/s11269-009-9450-1

Phillipson, J., Lowe, P., Proctor, A., & Ruto, E. (2012). Stakeholder engagement and knowledge exchange in environmental research. *Journal of Environmental Management*, *95*(1), 56–65. https://doi.org/10.1016/j.jenvman.2011.10.005

Rankoana, S. A. (2020). Climate change impacts on water resources in a rural community in Limpopo province, South Africa: A community-based adaptation to water insecurity. *International Journal of Climate Change Strategies and Management*, *12*, 587–598.

Rustinsyah, R., & Prasetyo, R. A. (2019). Stakeholder engagement in a water user association for agricultural irrigation management in the villages in Indonesia. *Journal of Water and Land Development*, *40*(1), 181–191. https://doi.org/10.2478/jwld-2019-0020

Sandker, M., Campbell, B. M., Ruiz-Pérez, M., Sayer, J. A., Cowling, R., Kassa, H., & Knight, A. T. (2010). The role of participatory modeling in landscape approaches to reconcile conservation and development. *Ecology and Society*, *15*(2), 1–16.

Sohns, A., Ford, J. D., Adamowski, J., & Robinson, B. E. (2021). Participatory modeling of water vulnerability in remote Alaskan households using causal loop diagrams. *Environmental Management*, *67*(1), 26–42.

Sutton-Brown, C. A. (2014). Photovoice: A methodological guide. *Photography and Culture*, *7*(2), 169–185.

Tremblay, C., & Harris, L. (2018). Critical video engagements: Empathy, subjectivity and changing narratives of water resources through participatory video. *Geoforum*, *90*, 174–182.

Voinov, A., Jenni, K., Gray, S., Kolagani, N., Glynn, P. D., Bommel, P., Prell, C., Zellner, M., Paolisso, M., Jordan, R., Sterling, E., Schimitt Olabisi, L., Giabbanelli, P., Sun, Z., Page, C. L., Elsawah, S., BenDor, T. K., Hubacek, K., Laursen, B. K., … Smajgl, A. (2018). Tools and methods in participatory modeling: Selecting the right tool for the job. *Environmental Modelling & Software*, *109*, 232–255. https://doi.org/10.1016/j.envsoft.2018.08.028

Wang, C., & Burris, M. A. (1994). Empowerment through photo novella: Portraits of participation. *Health Education and Behaviour*, *21*, 171–186.

REFERENCES

Alam, A., & Ihsan, S. (2012). Role of participatory rural appraisal in community development (A case study of Barani area development project in agriculture, live stock and forestry development in Kohat). *International Journal of Academic Research in Business and Social Sciences*, *2*(8), 25.

Al-Qubatee, W., Ritzema, H., Al-Weshali, A., van Steenbergen, F., & Hellegers, P. J. G. J. (2017). Participatory rural appraisal to assess groundwater resources in Al-Mujaylis, Tihama Coastal Plain, Yemen. *Water International*, *42*(7), 810–830.

Balazs, C. L., & Morello-Frosch, R. (2013). The three Rs: How community-based participatory research strengthens the rigor, relevance, and reach of science. *Environmental Justice*, *6*(1), 9–16.

Bainbridge, W. S., & Roco, M. C. (2015). *Handbook of science and technology convergence*. Springer.

Belay, D., Getachew, E., Azage, T., & Hegde, B. H. (2013). Farmers perceived livestock production constraints in Ginchi watershed area: Result of participatory rural appraisal. *International Journal of Livestock Production*, *4*(8), 128–134.

Berbés-Blázquez, M., Grimm, N. B., Cook, E. M., Iwaniec, D. M., Muñoz-Erickson, T. A., Hobbins, V., & Wahl, D. (2021). Assessing future resilience, equity, and sustainability in scenario planning. In *Resilient urban futures* (p. 113). Springer.

Bergold, J., & Thomas, S. (2012). Participatory research methods: A methodological approach in motion. *Historical Social Research/Historische Sozialforschung*, *13*(1), 191–222. https://doi.org/10.17169/fqs-13.1.1801

Berkhout, F., & Hertin, J. (2002). Foresight futures scenarios: developing and applying a participative strategic planning tool. *Greener Management International*, *37*, 37–52.

Birthisel, S. K., Eastman, B. A., Soucy, A. R., Paul, M., Clements, R. S., White, A., & Dittmer, K. M. (2020). Convergence, continuity, and community: a framework for enabling emerging leaders to build climate solutions in agriculture, forestry, and aquaculture. *Climatic Change*, *162*(4), 2181–2195.

Bisung, E., Elliott, S. J., Abudho, B., Karanja, D. M., & Schuster-Wallace, C. J. (2015). Using photovoice as a community based participatory research tool for changing water, sanitation, and hygiene behaviours in Usoma, Kenya. *BioMed Research International*, *2015*, 1–10.

Bonney, R., Cooper, C. B., Dickinson, J., Kelling, S., Phillips, T., Rosenberg, K. V., & Shirk, J. (2009). Citizen science: A developing tool for expanding science knowledge and scientific literacy. *Bioscience*, *59*(11), 977–984.

Bonney, R., Shirk, J. L., Phillips, T. B., Wiggins, A., Ballard, H. L., Miller-Rushing, A. J., & Parrish, J. K. (2014). Next steps for citizen science. *Science*, *343*(6178), 1436–1437.

Butler, C., & Adamowski, J. (2015). Empowering marginalized communities in water resources management: Addressing inequitable practices in participatory model building. *Journal of Environmental Management*, *153*, 153–162. https://doi.org/10.1016/j.jenvman.2015.02.010

Buytaert, W., Zulkafli, Z., Grainger, S., Acosta, L., Alemie, T. C., Bastiaensen, J., De Bièvre, B., Bhusal, J., Clark, J., Dewulf, A., & Foggin, M. (2014). Citizen science in hydrology and water resources: Opportunities for knowledge generation, ecosystem service management, and sustainable development. *Frontiers in Earth Science*, *2*, 26.

Cargo, M., & Mercer, S. L. (2008). The value and challenges of participatory research: Strengthening its practice. *Annual Review of Public Health*, *29*, 325–350.

Carr, G. (2015). Stakeholder and public participation in river basin management—An introduction. *Wiley Interdisciplinary Reviews: Water*, *2*(4), 393–405.

Cartwright, E., & Schow, D. (2016). Anthropological perspectives on participation in CBPR: Insights from the water project, Maras, Peru. *Qualitative Health Research*, *26*(1), 136–140. https://doi.org/10.1177/1049732315617480

Chandra, G. (2010). Participatory rural appraisal. In Katiha, P. K, Vaas, K. K., Sharma A. P., Bhaumik U. & Chandra, G., (eds). *Issues and tools for social science research in inland fisheries* (Vol. 163, pp. 286–302). Barrackpore, Kolkata, India. Bulletin: Central Inland Fisheries Research Institute.

Chesser, S., Porter, M. M., & Tuckett, A. G. (2020). Cultivating citizen science for all: ethical considerations for research projects involving diverse and marginalized populations. *International Journal of Social Research Methodology*, *23*(5), 497–508.

Chambers, R. (1992). *Rural appraisal: Rapid, relaxed and participatory*. Institute of Development Studies.

Chambers, R. (1994). Participatory rural appraisal (PRA): Challenges, potentials and paradigm. *World Development*, *22*(10), 1437–1454.

Chew, M., Maheshwari, B., & Somerville, M. (2019). Photovoice for understanding groundwater management issues and challenges of villagers in Rajasthan, India. *P. Groundwater for Sustainable Development*, *8*, 134–143.

Church, S. P., Payne, L. B., Peel, S., & Prokopy, L. S. (2019). Beyond water data: Benefits to volunteers and to local water from a citizen science program. *Journal of Environmental Planning and Management*, *62*(2), 306–326.

Conallin, J. C., Dickens, C., Hearne, D., & Allan, C. (2017). Chapter 7—Stakeholder engagement in environmental water management. In A. C. Horne, J. A. Webb, M. J. Stewardson, B. Richter, & M. Acreman (Eds.), *Water for the environment* (pp. 129–150). Academic Press. https://doi.org/10.1016/B978-0-12-803907-6.00007-3

Conley, A., & Moote, M. A. (2003). Evaluating collaborative natural resource management. *Society &Natural Resources*, *16*(5), 371–386.

Cornwall, A., & Jewkes, R. (1995). What is participatory research? *Social Science & Medicine*, *41*(12), 1667–1676.

Cummins, C., Doyle, J., Kindness, L., Lefthand, M. J., Bear Dont Walk, U. J., Bends, A. L., Broadaway, S. C., Camper, A. K., Fitch, R., Ford, T. E., Hamner, S., Morrison, A. R., Richards, C. L., Young, S. L., & Eggers, M. J. (2010). Community-based participatory research in Indian country: Improving health through water quality research and awareness. *Family & Community Health*, *33*(3), 166–174. https://doi.org/10.1097/FCH.0b013e3181e4bcd8

d'Aquino, P., & Bah, A. (2013). A participatory modeling process to capture indigenous ways of adaptability to uncertainty: Outputs from an experiment in West African Drylands. *Ecology and Society*, *18*(4), 16. https://doi.org/10.5751/ES-05876-180416

Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010). Citizen science as an ecological research tool: Challenges and benefits. *Annual Review of Ecology, Evolution, and Systematics*, *41*, 149–172.

Dittmer, K. M. (2020). Convergence, continuity, and community: a framework for enabling emerging leaders to build climate solutions in agriculture, forestry, and aquaculture. *Climatic Change*, *162*(4), 2181–2195.

Eaton, W. M., Braiser, K., Burbach, M., Whitmer, W., Engle, E., Burnham, A., Quimby, B., Chaudhary, A., Whitley, H., Delozier, J., Fowler, L., Wutich, A., Bausch, J. C., Beresford, M., Burkhart-Kriesel, M., Preisendanz, H., Williams, C. F., Watson, J., & Weigle, J. (2021). A conceptual model for enabling social and environmental change through stakeholder engagement in water resource management. *Society & Natural Resources.*, *34*, 1111–1132.

Elsawah, S., Hamilton, S. H., Jakeman, A. J., Rothman, D., Schweizer, V., Trutnevyte, E., Carlsen, H., Drakes, C., Frame, B., Fu, B., Guivarch, C., Haasnoot, M., Kemp-Benedict, E., Kok, K., Kosow, H., Ryan, M., & van Delden, H. (2020). Scenario processes for socio-environmental systems analysis of futures: A review of recent efforts and a salient research agenda for supporting decision making. *Science of the Total Environment*, *729*, 138393.

Estrella, M., Blauert, J., Campilan, D., Gaventa, J., Gonsalves, J., Johnson, D. & Ricafort, R. (Eds.). (2000). *Learning from change: Issues and experiences in participatory monitoring and evaluation*. IDRC.

Evers, M., Jonoski, A., Maksimovič, Č., Lange, L., Ochoa Rodriguez, S., Teklesadik, A., Cortes Arevalo, J., Almoradie, A., Eduardo Simões, N., Wang, L., & Makropoulos, C. (2012). Collaborative modelling for active involvement of stakeholders in urban flood risk management. *Natural Hazards & Earth Systems Science*, *12*, 2821–2842. https://doi.org/10.5194/nhess-12-2821-2012

Fantini, E. (2017). Picturing waters: a review of Photovoice and similar participatory visual research on water governance. *Wiley Interdisciplinary Reviews: Water*, *4*(5), e1226.

Ferguson, L., Chan, S., Santelmann, M., & Tilt, B. (2017). Exploring participant motivations and expectations in a researcher-stakeholder engagement process: Willamette Water 2100. *Landscape and Urban Planning*, *157*, 447–456. https://doi.org/10.1016/j.landurbplan.2016.08.014

Ferreyra, C. (2006). Practicality, positionality, and emancipation: reflections on participatory action research with a watershed partnership. *Systemic Practice and Action Research*, *19*(6), 577–598.

Gaddis, E. J. B., Falk, H. H., Ginger, C., & Voinov, A. (2010). Effectiveness of a participatory modeling effort to identify and advance community water resource goals in St. Albans, Vermont. *Environmental Modelling and Software*, *25*(11), 1428–1438. https://doi.org/10.1016/j.envsoft.2009.06.004

Gielczewski, M., Stelmaszczyk, M., Piniewski, M., & Okruszko, T. (2011). How can we involve stakeholders in the development of water scenarios? Narew River Basin case study. *Journal of Water and Climate Change*, *2*(2-3), 166–179.

Grassini, L. (2018). Participatory water governance between theories and practices: Learning from a community-based initiative in India. *International Journal of Water Resources Development*, *35*(3), 404–429.

Gray, S., Voinov, A., Paolisso, M., Jordan, R., BenDor, T., Bommel, P., Glynn, P., Hedelin, B., Hubacek, K., Introne, J., Kolagani, N., Laursen, B., Prell, C., Schmitt Olabisi, L., Singer, A., Sterling, E., & Zellner, M. (2018). Purpose, processes, partnerships, and products: Four Ps to advance participatory socio-environmental modeling. *Ecological Applications*, *28*(1), 46–61. https://doi.org/10.1002/eap.1627

Guta, A., Flicker, S., & Roche, B. (2013). Governing through community allegiance: A qualitative examination of peer research in community-based participatory research. *Critical Public Health*, *23*(4), 432–451. https://doi.org/10.1080/09581596.2012.761675

Henriques, C., Garnett, K., Weatherhead, E. K., Lickorish, F. A., Forrow, D., & Delgado, J. (2015). The future water environment—Using scenarios to explore the significant water management challenges in England and Wales to 2050. *Science of the Total Environment*, *512*, 381–396.

Hubacek, K., Ravera, F., Tarrason, D., & Prell, C. (2017). Participatory Modeling for Environmental Decision-making. In Douglas, R., Noel, C., Michael, F. G., Audrey, K., Weidong, L. & Richard A., (eds). *International Encyclopedia of Geography: People, the Earth, Environment, and Technology*. Hoboken, NJ: John Wiley & Sons, Inc..

Irvin, R. A., & Stansbury, J. (2004). Citizen participation in decision making: Is it worth the effort? *Public Administration Review*, *64*(1), 55–65.

Irwin, A. (2002). *Citizen science: A study of people, expertise and sustainable development*. Routledge.

Iwaniec, D. M., Cook, E. M., Davidson, M. J., Berbés-Blázquez, M., Georgescu, M., Krayenhoff, E. S., Middel, A., Sampson, D. A., & Grimm, N. B. (2020). The co-production of sustainable future scenarios. *Landscape and Urban Planning*, *197*, 103744.

Kemmis, S., & McTaggart, R. (2007). Communicative action and the public sphere. *The Sage handbook of qualitative research*, 559–603.

Keremane, G. B., & McKay, J. M. (2012). Picturing sustainable water resources management: Photo-conversations with irrigators and policymakers. *International Journal of Environmental, Cultural, Economic and Social Sustainability*, *7*(6), 145–153.

Keeler, L. W., Wiek, A., White, D. D., & Sampson, D. A. (2015). Linking stakeholder survey, scenario analysis, and simulation modeling to explore the long-term impacts of regional water governance regimes. *Environmental Science & Policy*, *48*, 237–249.

Khair, S., Ashfaq, M., Ali, A., Akhtar, S., Mangan, T., & Allan, C. (2021). *Participatory rural appraisal: Starting the co-inquiry into groundwater and livelihoods*.

Kidd, S. A., & Kral, M. J. (2005). Practicing participatory action research. *Journal of counseling psychology*, *52*(2), 187.

Kimmich, C., Gallagher, L., Kopainsky, B., Dubois, M., Sovann, C., Buth, C., & Bréthaut, C. (2019). Participatory modeling updates expectations for individuals and groups, catalyzing behavior change and collective action in water-energy-food nexus governance. *Earth's Future*, *7*(12), 1337–1352.

King, A. B., & Thornton, M. (2016). Staying the course: Collaborative modeling to support adaptive and resilient water resource governance in the inland northwest. *Water (Basel)*, *8*(6), 232. https://doi.org/10.3390/w8060232

Kobori, H., Dickinson, J. L., Washitani, I., Sakurai, R., Amano, T., Komatsu, N., Kitamura, W., Takagawa, S., Koyama, K., Ogawara, Takao, & Miller-Rushing, A. J. (2016). Citizen science: A new approach to advance ecology, education, and conservation. *Ecological Research*, *31*(1), 1–19. https://link.springer.com/article/10.1007/s11284-015-1314-y

Kowalski, K., Stagl, S., Madlener, R., & Omann, I. (2009). Sustainable energy futures: Methodological challenges in combining scenarios and participatory multi-criteria analysis. *European Journal of Operational Research*, *197*(3), 1063–1074.

Krueger, T., Maynard, C., Carr, G., Bruns, A., Mueller, E. N., & Lane, S. (2016). A transdisciplinary account of water research. *Wiley Interdisciplinary Reviews. Water*, *3*(3), 369–389.

Kythreotis, A. P., Mantyka-Pringle, C., Mercer, T. G., Whitmarsh, L. E., Corner, A., Paavola, J., Chambers, C., Miller, B. A., & Castree, N. (2019). Citizen social science for more integrative and effective climate action: A science-policy perspective. *Frontiers in Environmental Science*, *7*, 10.

Lakhina, S. J. (2019). Co-learning disaster resilience: A person-centred approach to understanding experiences of refuge and practices of safety. *PhD dissertation*. University of Wollongong, Australia.

Lakhina, S. J., Sutley, E. J., & Wilson, J. (2021). "How do we actually do convergence" for disaster resilience? Cases from Australia and the United States. *International Journal of Disaster Risk Science*, *12*, 1–13.

Lammerink, M. P. (1998). Community managed rural water supply: experiences from participatory action research in Kenya, Cameroon, Nepal, Pakistan, Guatemala, and Colombia. *Community Development Journal*, *33*(4), 342–352.

Landström, C., Becker, M., Odoni, N., & Whatmore, S. J. (2019). Community modelling: A technique for enhancing local capacity to engage with flood risk management. *Environmental Science & Policy*, *92*, 255–261.

Landström, C., Whatmore, S. J., Lane, S. N., Odoni, N. A., Ward, N., & Bradley, S. (2011). Coproducing flood risk knowledge: Redistributing expertise in critical 'participatory modelling'. *Environment and Planning A*, *43*(7), 1617–1633.

Lane, S. N., Odoni, N., Landström, C., Whatmore, S. J., Ward, N., & Bradley, S. (2011). Doing flood risk science differently: An experiment in radical scientific method. *Transactions of the Institute of British Geographers*, *36*(1), 15–36.

Latz, A. O., Phelps-Ward, R., Royer, D., & Peters, T. (2016). Photovoice as methodology, pedagogy, and partnership-building tool: A graduate and community college student collaboration. *Journal of Public Scholarship in Higher Education*, *6*, 124–142.

Lauer, F. I., Metcalf, A. L., Metcalf, E. C., & Mohr, J. J. (2018). Public engagement in social-ecological systems management: An application of social justice theory. *Society & Natural Resources*, *31*(1), 4–20. https://doi.org/10.1080/08941920.2017.1364456

Leurs, R. (1996). Current challenges facing participatory rural appraisal. *Public Administration and Development*, *16*(1), 57–72.

Macaulay, A. C. (2017). Participatory research: What is the history? Has the purpose changed? *Family Practice*, *34*(3), 256–258.

Mackenzie, J., Tan, P.-L., Hoverman, S., & Mooney, C. (2012). The value and limitations of participatory action research methodology. *Journal of Hydrology*, *474*, 11–21.

McTaggart, R. (1991). Principles for participatory action research. *Adult education quarterly*, *41*(3), 168–187.

Millennium Ecosystem Assessment (2005). *Ecosystems and human well-being*. Scenarios, Vol. 2, Island, Washington.

Mitchell, F. M. (2018). "Water is life": Using photovoice to document American Indian perspectives on water and health. *Social Work Research*, *42*(4), 277–289.

Nikolakis, W., & Quentin Grafton, R. (2014). Fairness and justice in indigenous water allocations: insights from Northern Australia. *Water Policy*, *16*(S2), 19–35.

Nilsson, A. E., Carson, M., Cost, D. S., Forbes, B. C., Haavisto, R, Karlsdottir, A., & Pelyasov, A. (2021). Towards improved participatory scenario methodologies in the Arctic. *Polar Geography*, *44*(2), 75–89.

Njue, N., Kroese, J. S., Gräf, J., Jacobs, S. R., Weeser, B., Breuer, L., & Rufino, M. C. (2019). Citizen science in hydrological monitoring and ecosystem services management: State of the art and future prospects. *Science of the Total Environment*, *693*, 133531.

Nyaki, A., Gray, S., Lepczyk, C. A., Skibins, J. C., & Rentsch, D. (2014). Local-scale dynamics and local drivers of bushmeat trade. *Conservation Biology*, *28*(5), 1403–1414. https://doi.org/10.1111/cobi.12316

Paul, J. D., Buytaert, W., Allen, S., Ballesteros-Cánovas, J. A., Bhusal, J., Cieslik, K., Clark, J., Dugar, S., Hannah, D. M., Stoffel, M., Dewulf, A., Dhital, M. R., Liu, W., Nayaval, J. L., Neupane, B., Schiller, A., Smith, P., & Supper, R. (2018). Citizen science for hydrological risk reduction and resilience building. *Wiley Interdisciplinary Reviews: Water*, *5*(1), e1262.

Peek, L., Tobin, J., Adams, R. M., Wu, H., & Mathews, M. C. (2020). A framework for convergence research in the hazards and disaster field: The natural hazards engineering research infrastructure CONVERGE facility. *Frontiers in Built Environment*, *6*, 110.

Pereira, E., Queiroz, C., Pereira, H. M., & Vicente, L. (2005). Ecosystem services and human well-being: A participatory study in a mountain community in Portugal. *Ecology and Society*, *10*(2), 1–24.

Petras, E. M., & Porpora, D. V. (1993). Participatory research: Three models and an analysis. *The American Sociologist*, *24*(1), 107–126.

Prell, C., Hesed, C. D. M., Johnson, K., Paolisso, M., Teodoro, J. D., & Van Dolah, E. (2021). Transdisciplinarity and shifting network boundaries: The challenges of studying an evolving stakeholder network in participatory settings. *Field Methods*, *33*, 405–416.

Proskuryakova, L. N., Saritas, O., & Sivaev, S. (2018). Global water trends and future scenarios for sustainable development: the case of Russia. *Journal of cleaner production*, *170*, 867–879.

Quimby, B., & Beresford, M. (2023). Participatory modeling: A methodology for engaging stakeholder knowledge and participation in social science research. *Field Methods*.

Radonic, L., & Jacob, C. E. (2021). Examining the cracks in universal water coverage: Women document the burdens of household water insecurity. *Water Alternatives*, *14*(1), 60–78.

Rae, M., Miró, A., Hall, J., O'Brien, K., & O'Brien, D. (2019). Evaluating the validity of a simple citizen science index for assessing the ecological status of urban drainage ponds. *Ecological Indicators*, *98*, 1–8.

Rammelt, C. F. (2014). Participatory action research in marginalised communities: Safe drinking water in rural Bangladesh. *Systemic Practice and Action Research*, *27*(3), 195–210.

Rasmussen, L. M., & Cooper, C. (2019). Citizen science ethics. *Citizen Science: Theory and Practice*, *4*(1).

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*(10), 2417–2431.

Reed, M. S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., Huber, T., Neumann, R. K., Oughton, E. A., Sidoli del Ceno, J., & van Delden, H. (2018). A theory of participation: What makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, *26*(S1), S7–S17. https://doi.org/10.1111/rec.12541

Ricaurte, L. F., Wantzen, K. M., Agudelo, E., Betancourt, B., & Jokela, J. (2014). Participatory rural appraisal of ecosystem services of wetlands in the Amazonian Piedmont of Colombia: Elements for a sustainable management concept. *Wetlands Ecology and Management*, *22*(4), 343–361.

Richardson, L. (2016). Citizen social science and policy making. In G. Stoker & M. Evans (Eds.), *Evidence-based policy making in the social sciences: Methods that matter* (pp. 207–228). Policy Press.

Sadanandan, S, Natarajan, P., Antony, J., & Vipinkumar, V. P. (2007). Data tools: Participatory Rural Appraisal Techniques. *Rajiv Gandhi Chair in Contemporary Studies Cochin University of Science and Technology*.

Sampson, D. A., Cook, E. M., Davidson, M. J., Grimm, N. B., & Iwaniec, D. M. (2020). Simulating alternative sustainable water futures. *Sustainability Science*, *15*, 1199–1210.

Shell. (2005). *Shell global scenarios to 2025*. London, UK: Global Business Environment.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology & Evolution*, *24*(9), 467–471.

Sterling, E. J., Zellner, M., Jenni, K., Leong, K. M., Glynn, P. D., BenDor, T. K., Bommel, T. K., Hubacek, K., Jetter, A. J., Jordan, R., Schmitt Olabisi, L., Paolisso, M., & Gray, S. (2019). Try, try again: Lessons learned from success and failure in participatory modeling. *Elementa Science of the Anthropocene*, *7*(1), 9. https://doi.org/10.1525/elementa.347

SturtzSreetharan, C. (2020). Citizen sociolinguistics: A data collection approach for hard-to-capture naturally occurring language data. *Field Methods*, *32*(3), 327–334.

Tipaldo, G., & Allamano, P. (2017). Citizen science and community-based rain monitoring initiatives: An interdisciplinary approach across sociology and water science. *Wiley Interdisciplinary Reviews: Water*, *4*(2), e1200.

van Buuren, A., van Meerkerk, I., & Tortajada, C. (2019). Understanding emergent participation practices in water governance. *International Journal of Water Resources Development*, *35*(3), 367–382.

van Eeten, M. J., Loucks, D. P., & Roe, E. (2002). Bringing actors together around large-scale water systems: Participatory modeling and other innovations. *Knowledge, Technology & Policy*, *14*(4), 94–108.

Voinov, A., & Gaddis, E. J. B. (2008). Lessons for successful participatory watershed modeling: A perspective from modeling practitioners. *Ecological Modelling*, *216*(2), 197–207. https://doi.org/10.1016/j.ecolmodel.2008.03.010

Wallerstein, N., & Duran, B. (2010). Community-based participatory research contributions to intervention research: The intersection of science and practice to improve health equity. *American Journal of Public Health*, *100*(Suppl 1), S40–S46. https://doi.org/10.2105/AJPH.2009.184036

Wallerstein, N., Duran, B., & Oetzel, J. G. (2017). In M. Minkler (Ed.), *Community-based participatory research for health: Advancing social and health equity*. John Wiley & Sons.

Walker, D. W., Smigaj, M., & Tani, M. (2021). The benefits and negative impacts of citizen science applications to water as experienced by participants and communities. *Wiley Interdisciplinary Reviews: Water*, *8*(1), e1488.

Wang, C., & Burris, M. A. (1997). Photovoice: Concept, methodology, and use for participatory needs assessment. *Health Education & Behavior*, *24*(3), 369–387.

Wehn, U., & Almomani, A. (2019). Incentives and barriers for participation in community-based environmental monitoring and information systems: A critical analysis and integration of the literature. *Environmental Science & Policy*, *101*, 341–357.

Wehn, U., Collins, K., Anema, K., Basco-Carrera, L., & Lerebours, A. (2018). Stakeholder engagement in water governance as social learning: Lessons from practice. *Water International*, *43*(1), 34–59. https://doi.org/10.1080/02508060.2018.1403083

Westerhoff, P., Wutich, A., & Carlson, C. (2021). Value propositions provide a roadmap for convergent research on environmental topics. *Environmental Science & Technology*, *55*(20), 13579–13582. https://doi.org/10.1021/acs.est.1c05013

Wood, B., & Kallestrup, P. (2021). Benefits and challenges of using a participatory approach with community-based mental health and psychosocial support interventions in displaced populations. *Transcultural Psychiatry*, *58*(2), 283–292. https://doi.org/10.1177/1363461520983626

Workman, C. L., Cairns, M. R., de los Reyes III, F. L., & Verbyla, M. E. (2021). Global water, sanitation, and hygiene approaches: Anthropological contributions and future directions for engineering. *Environmental Engineering Science*, *38*(5), 402–417.

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