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Building Public Health Emergency Preparedness, Response, and Recovery Capabilities through Disaster Citizen Science: Perspectives from Local Health Department, Academic, and Community Representatives

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Abstract

Context: Disaster citizen is the use of scientific methods by the public to address preparedness, response, or recovery needs. Disaster citizen science applications with public health relevance are growing in academic and community sectors but integration with public health emergency preparedness, response, and recovery (PHEPRR) agencies is limited.

Objective: We examined how local health departments and community-based organizations have used citizen science to build public health preparedness and response (PHEP) capabilities. The purpose of this study is to help local health departments make use of citizen science to support PHEPRR.

Design: We conducted semi-structured telephone interviews (n=55) with local health department (LHD), academic, and community representatives engaged or interested in citizen science. We used inductive and deductive methods to code and analyze interview transcripts.

Setting: U.S. and international community-based organizations and U.S. local health departments

Participants: Participants included 18 LHD representatives reflecting diversity in geographic regions and population sizes served and 31 disaster citizen science project leaders and 6 citizen science thought leaders.

Main outcomes: We identified challenges LHDs and academic and community partners face in using citizen science for PHEPRR as well as strategies to facilitate implementation.

Results: Academic and community-led disaster citizen science activities aligned with many PHEP capabilities including community preparedness, community recovery, public health surveillance and epidemiological investigation, and volunteer management. All participant groups discussed challenges related to resources, volunteer management, collaborations, research quality, and institutional acceptance of citizen science. LHD representatives noted unique barriers due to legal and regulatory constraints and their role in using citizen science data to inform public health decisions. Strategies to increase institutional acceptance included enhancing policy support for citizen science, increasing volunteer management support, developing best practices

for research quality, strengthening collaborations, and adopting lessons learned from relevant PHEPRR activities.

Conclusions: There are challenges to overcome in building PHEPRR capacity for disaster citizen science but also opportunities for LHDs to leverage the growing body of work, knowledge, and resources in academic and community sectors.

Introduction

Large-scale disasters and public health emergencies such as the COVID-19 pandemic have underscored the challenges facing U.S. public health preparedness systems, including limited surveillance and response capacity, government mistrust, and public communication difficulties. Federal agencies, such as the U.S. Federal Emergency Management Agency, have raised the need to achieve a "whole community" approach to public health emergency preparedness, response, and recovery (PHEPRR) in which individuals, communities, and government work together to build resilience.[1] Achieving this vision of a strengthened U.S. public health preparedness system might depend in part upon innovative models for PHEPRR research, such as citizen science, which emphasize local data collection, empowerment of local actors, cross-sectoral collaborations, and equitable processes and outcomes.[2–4]

Citizen science entails the use of scientific principles and methods by members of the public to understand phenomena in the world. In practice, citizen science encompasses a range of models, including community-led initiatives (collegial citizen science), initiatives led by professional researchers that enlist public volunteers (contributory citizen science), or partnership-based initiatives that split decision-making between professional researchers and community stakeholders (collaborative citizen science).[5] Citizen science as a field is growing rapidly as evidenced by academic and governmental actions to increase professionalization of the field and encourage federal science agencies to use citizen science to achieve their missions.[6]

Compared to fields such as ecology and environmental science however, the use of citizen science for PHEPRR is limited. Two recent reviews, one conducted by authors of this paper, identified over 200 projects focused on disaster preparedness, response, or recovery, but just a handful led by health departments.[7,8] Many projects led by academic, non-governmental, or community groups had relevance for public health, but activities or data were not integrated into larger PHEPRR systems. The breadth of disaster citizen science activities occurring outside traditional public health agencies is increasing rapidly.[7] To be at the forefront of innovations that leverage community engagement in research, public health entities need studies that provide practical guidance on the relevance and utility of citizen science for PHEPRR.

Cross-sectoral collaborations are integral to the success of PHEPRR, and the same holds true for citizen science initiatives.[9] Therefore, in this article we describe the results of a qualitative study that synthesized perspectives on disaster citizen science from local health department (LHD) representatives and other government officials, community organization leaders, and academic researchers. We use the public health emergency preparedness

and response (PHEP) capabilities developed by the Centers for Disease Control and Preparedness (CDC) as a framework for organizing citizen science activities through the capabilities they could support.[10]

Methods

Study sample

Between January 2017 and April 2019, we conducted 60-minute interviews via telephone with 18 LHD representatives, 31 disaster citizen science project leaders, and six citizen science subject matter experts (i.e., academic researchers with expertise in citizen science and individuals affiliated with funding organizations supporting citizen science). To recruit LHD representatives, we collaborated with the National Association of County and City Health Officials (NACCHO). NACCHO provided contact information for a sample of LHDs diverse in terms of size of population served and U.S. census region. We identified project leaders through an inventory of disaster citizen projects compiled by members of the study team.[6] We opted for a purposive sampling technique to obtain diverse perspectives across citizen science models, participant organizations, disaster types, and project locations. This approach helped us explore citizen science use cases across diverse contexts. We identified subject matter experts through the project inventory and team networks. Subject matter experts came from government, academic organizations, and funding organizations and offered either general perspectives about the field of citizen science and/or specific insight into areas of interest such as the role of government, ethical considerations, or citizen science technologies.

We contacted all potential participants by email. Acceptance rates varied by sub-group: 95% for LHDs (18/19 contacted), 60% for disaster citizen science project leaders (31/52 contacted), and 86% for thought leaders (6/7 contacted).

For LHD representatives, we developed a 15-item semi-structured interview guide focusing on knowledge, attitudes, and experiences related to citizen science. For project and thought leaders, we developed a 16-item semi-structured interview guide focusing on experiences implementing citizen science projects and perceptions on impacts, uses, and challenges (Appendix A). Domains and questions invalided in the interview guides were informed by literature reviews and our knowledge of the field of citizen science from related work.[7] We recorded, transcribed, and deidentified each interview. The interviews were approved by the U.S. Office of Management and Budget in compliance with the Paperwork Reduction Act (OMB Control No: 0920–1236, exp. 06/30/2021). RAND's Institutional Review Board reviewed and approved the study.

Analysis

Interviews were coded thematically using Dedoose version 8.0.35, a web application for managing and analyzing qualitative data.[11] To define thematic areas, we performed a deductive approach to coding using interview guide topics: (a) experiences with citizen science; (b) challenges; and (c) facilitators of use or impact. In addition, we carried out an inductive analysis through line-by-line coding to uncover unanticipated themes.

We also coded projects according to alignment with key functions or tasks within each PHEP capability. (Table 2). The 15 PHEP capabilities are national standards intended to build the PHEPRR capacity of state, local, tribal, and territorial public health systems. The capabilities provide an instructive framework for evaluating the potential of disaster citizen science as they demonstrate cornerstone needs for local communities to prepare for, respond to, and recover from disasters (e.g., the ability to support community-level preparedness and recovery, to coordinate emergency operations, perform effective messaging, engage in surveillance, etc.). Using this framework, we identify challenges PHEPRR systems might face in using citizen science strategies for effective implementation.

We created a hierarchically organized codebook to summarize themes and identify patterns across transcripts. Two members of the study team coded the interview transcripts. Before independent coding, the last author trained team members on use of the codebook. Team members then applied codes to a common set of interview excerpts. Once a satisfactory level of agreement was reached (kappa > 0.7), the team members divided and coded transcripts independently. Once coding was completed, we thematically analyzed and summarized excerpts.

Results

Disaster citizen science experience and alignment with PHEP capabilities

See Table 1 for participant characteristics. We catalogued 26 projects run by academic (n=13), community (n=11), and non-LHD government (n=2) project leaders (Table 3). These projects demonstrate successful instances of citizen science being deployed to enhance local PHEP capabilities. Projects included scientific investigations, monitoring and surveillance programs, participatory research initiatives, crowdsourcing activities, and community-led recovery efforts. In addition, we identified 11 projects discussed by seven LHDs that were either established activities (n=4), pilot or early-stage efforts (n=5), or community-led with LHD involvement (n=2) (**Table 4**). The 18 LHD representatives in our final sample were primarily preparedness coordinators or other preparedness staff (n=12). The project leaders and thought leaders in our final sample reflected academic, government, and community sectors. Twenty two projects were U.S.-based.

Most LHD representatives expressed unfamiliarity with citizen science and doubt over LHD readiness to engage with the approach. However, the majority were also enthusiastic about the potential of citizen science. As one LHD representative remarked, "*I think it's an awesome opportunity…to have people be more involved or more aware of the health department...it's...another great way to foster emergency planning and emergency response capabilities as a whole community.*"

In the study sample, disaster citizen science activities aligned with four out of 15 PHEP capabilities. Projects falling under **community preparedness** tended to involve community education or training or focused on community risk assessment. For example, LHD representatives reported that they relied on citizen science methods, like Community Assessments for Public Health Emergency Response and dialogue sessions to identify community capabilities, perceptions, and vulnerabilities in advance of disasters;

meaningfully engage communities in planning efforts; and establish inventories of disaster effects. Projects under **community recovery** typically involved identification of community recovery needs, support for recovery operations or implementation of corrective actions. For example, one respondent noted that in the aftermath of a natural disaster that disrupts electrical or transportation infrastructure, local agencies rely on decentralized observational networks to identify potential hazards and recovery priorities. We categorized most projects as having relevance for **public health surveillance and epidemiological investigation**, either in supporting surveillance activities and/or providing recommendations for mitigation actions. For example, one project leader noted their local department of environmental management used citizen science data to identify potential red flags related to water system contamination, which it then investigated for potential regulatory action. Finally, we categorized projects that involved sustained volunteer activity, such as surveillance programs that relied on large numbers of volunteers and crowdsourced data interpretation activities, as supporting **volunteer management**. While we did not directly categorize projects under **information sharing** or **responder safety**, we note these capabilities would be relevant for supporting disaster citizen science projects by ensuring necessary information sharing between community or academic partners, volunteers, and LHDs, and the safety of citizen science volunteers.

Citizen science challenges and facilitators

We identified five cross-cutting challenges applicable across capabilities: resources; volunteer management; collaborations; research quality; and acceptance. In addition, we present facilitators recommended by participants to address each challenge.

Resource challenges and facilitators—Almost all participants reported funding as a major citizen science challenge. LHD representatives noted that health departments often operate under limited resources. Project leaders described how funding shortfalls affected project management and sustainability.

To address resource challenges, LHD representatives recommended enhanced support for disaster citizen science in PHEPRR funding, guidance, and programming. For example, several representatives expressed that gaining buy-in for disaster citizen science was a challenge given that existing departmental priorities or PHEP cooperative agreements did not emphasize its utility.[10] Several project leaders noted creative ways in which they supported projects, including use of personal funds, membership fees for citizen science data users, and hiring students for administrative tasks. Many projects depended upon partnerships for resource exchange (e.g., technical expertise, access to equipment, community knowledge). Finally, many project leaders noted that newly available web platforms that facilitated data sharing could assist emerging projects looking to scale data collection and classification. As one participant observed, *“now there’s…programs like Zooniverse, SciStarter, and* citizenscience.org *or* citsci.org, *where they have platforms available…that you can…get started with instead of…trying to create this totally from scratch.”*

Volunteer management challenges and facilitators—LHD representatives considered the absence of resources required to recruit, train, and sustain volunteer engagement as a barrier to citizen science, particularly in remote or rural areas. Several representatives reported limited staff availability for training, managing, and retaining volunteers. In addition, representatives were concerned about injuries and liabilities and legal issues related to labor laws. In contrast, project leaders described challenges related to recruitment, motivation, and sustaining participation over time.

To address challenges, LHD representatives suggested partnering with groups that could assist in recruiting, training, or managing volunteers. Many LHD representatives noted they successfully trained members of the Medical Reserve Corps (MRC) without legal/ethical issues to conduct surveys or damage assessments. Participants noted the importance of ensuring safe data collection by establishing training protocols and providing guidance to volunteers. Project leaders encouraged laying the groundwork for volunteer efforts before disasters take place. As one participant noted, *"A disaster is not the time to introduce something new."* To engage with and motivate volunteers, several project leaders expressed the importance of being responsive to needs and demonstrating the utility of data collected. As one participant observed, *"People get really irritated…when they invest a lot of time and energy and they don't see any results… Anytime you can get data … turned around as quickly as possible… I think continues the engagement."* Several projects enabled volunteers to near-instantaneously see the data they contributed to public datasets.

Collaboration challenges and facilitators—All participant groups raised issues with developing harmonious working relationships with various citizen science stakeholders, including citizen scientists, advocates, members of community-based organizations, residents, and academic researchers. Project leaders noted the importance of respect and shared values among community groups and technical experts.

LHD representatives noted several steps citizen scientists could take to better collaborate with health departments. For example, citizen scientists or project leaders could engage with LHDs through trusted partners, establish relationships within LHDs, become familiar with an agency's structure, decision-making processes, constraints, and data needs, and ensure that appropriate agencies are engaged from the outset of an activity. This perspective was echoed by community-led citizen science groups that recommended that robust procedures and collaborations should be in place before issuing calls for action. As one project leader stated, "*I really encourage [volunteers] to get the protocols worked out so that they know exactly what they're doing. Reach out in more of a collaborative approach to the local authorities.*"

Finally, according to a project leader, good relationships also depend upon stakeholders understanding the different roles that each actor plays in PHEPRR. As one project leader noted, "*We may still find that there's a role for civil society to play in…performing the functions that I think government should be.*"

Research quality challenges and facilitators—Many LHD representatives saw citizen science data quality as a major barrier to acceptance and use and noted the

need for data verification given the risk of publishing faulty information and losing the public's trust. Project and thought leaders acknowledged challenges in ensuring research quality but instituted processes in their projects to address them. Strategies included volunteer trainings and regular communications, employing easy-to-use data collection tools, expert validation procedures, instituting redundancies in data collection or analytic processes, and incorporating learning curves into project timelines. Many project leaders noted that collaborations improved analyses, either through adopting lessons learned from other projects, accessing resources or expertise, or integrating feedback from important stakeholders.

Thought leaders also noted that not all actions require uniform precision, and that data could be used differently depending on quality. According to one participant, "*Data doesn't have to be perfect to be perfectly usable for decision making. … I think sorting the boundaries of when it needs to be precise and when it doesn't is important.*" Project leaders also highlighted the importance of clarifying project objectives to inform the level of rigor needed for data collection.

Regarding research processes, LHD representatives noted that academic partners could help with ethical challenges such as privacy concerns and human subjects research protections.

Acceptance challenges and facilitators—All interview groups raised challenges related to general acceptance of disaster citizen science. Many LHD representatives expressed some degree of mistrust toward citizen science data, which may stem, in part, from perceptions about the potential for biased or inaccurate data. As one LHD representative described, "*There's just a real nervousness about going into this until there's clear guidelines on…the ethics and methodology…There's a feeling right now…[that]… citizen science is…research happening without…a solid methodology.*" Several project leaders expressed frustration with professional skepticism about the worth of citizen science data or its potential to undermine credibility. From the perspective of many project leaders, government agencies should look favorably upon data contributions.

In addition to skepticism, an LHD representative noted that citizen science may be seen as a threat to existing funding, as, "*work will be pushed onto volunteers to…justify reduced funding,*" However, one thought leader pushed back against this idea, saying, "*We need to… have the people inside look at it as not feeling threatened…It's about symbiosis.*" Project leaders suggested their role was not to supplant agency functions, but to help agencies fulfill their mission. As one participant said, "*We're not trying to take away the government's role …In the best world where we monitor a site and…find it's polluted, a success for us is…the agency…taking [it] on.*"

Project leaders touted the benefits of citizen science for obtaining local data. As one project leader said, "*I think…citizen volunteers… have a more intimate knowledge with … the location that they're looking to protect. And they have a lot of valuable information … on where their resources can be best spend.*" LHD representatives and thought leaders expressed that LHDs need more information about the cost-effectiveness of citizen science

and evidence of project successes to build a culture of acceptance around disaster citizen science.

Discussion

We conducted a qualitative study of multi-stakeholder perspectives on the potential of disaster citizen science for PHEPRR. In our sample, respondents expressed positive attitudes about the utility of citizen science for LHD activities and described instances in which citizen science was being used to build PHEP capabilities; however, we found that uptake by traditional PHEPRR entities such as LHDs lagged behind other preparedness, response, and recovery stakeholders, like citizen science organizations.

There is evidence that citizen science could support PHEP capabilities

We found many examples of disaster citizen science that aligned with several PHEP capabilities (Tables 3 and 4). However, the use of citizen science in several capabilities has yet to be explored (e.g., emergency operations coordination, emergency public information and warning, medical countermeasures). While some of these functions are inherently governmental, we note opportunities to apply citizen science to support specific functions within these capabilities or to leverage skilled medical and public health professionals as volunteer researchers. For example, crowdsourcing approaches could be adopted to evaluate and improve public health messaging in real-time or assess and mitigate misinformation (emergency public information and warning).[12] Citizen science protocols for community health assessments could be adapted for needs assessments carried out by medical or lay volunteers to support mass care or medical surge capabilities.[13] Community-based research or crowdsourcing could be used for assessment tasks related to informing physical dispensing logistics and communication strategies to promote trust and community participation (medical countermeasures), developing or evaluating mental health services (fatality management), or assessing the acceptability and feasibility of non-pharmaceutical interventions before community deployment. As part of larger data gathering efforts, community reporting could help inform monitoring activities related to population health (mass care and sheltering), adverse events (medical countermeasures), inventory tracking (medical material), and effectiveness of non-pharmaceutical interventions. These use cases demonstrate how citizen science could support PHEP by increasing public health relevance to local context and needs.

LHD efforts in implementing disaster citizen science may be enhanced through external collaboration and cooperation

All participant groups raised challenges regarding resources, volunteer management, collaborations, and research quality. However, LHD representatives tended to discuss different kinds of challenges, which largely reflect the institutional constraints health departments operate in. LHD representatives discussed potential legal and regulatory barriers to use of volunteers, data privacy and security, and fundraising.[14] Such concerns did not arise to the same extent in project leader interviews. In addition, many challenges discussed by LHD representatives appeared to reflect their position as local decision-makers. Not only could LHDs engage in citizen science for data collection, but they could also

act upon the data to address underlying problems. However, as trusted public health stewards, LHDs might be more cautious in collaborative endeavors and concerned about data inaccuracies and quality.

Many facilitators discussed by project leaders, such as membership fees for funding, ensuring high levels of communication and responsivity or utilizing a variety of data collection tools, indicate that citizen science projects require some degree of flexibility for successful implementation. However, given their legal and regulatory constraints and decision-maker role, LHDs may currently lack the flexibility needed for implementation of disaster citizen science projects on their own. These constraints hamper integration of disaster citizen science into official PHEPRR systems, but growth in the field overall creates engagement opportunities. Cross-sectoral partnerships and multi-stakeholder efforts that leverage the growing body of work in academic and community environments might help boost LHD involvement and expand PHEPRR engagement with disaster citizen science.

Building disaster citizen science capacity by increasing trust and acceptance

A running theme across all participant groups was the need to increase institutional trust and acceptance of citizen science as a means for removing barriers to its use. Synthesizing across interviews, we identified five strategies for increasing institutional trust and acceptance of citizen science that reflect both vertical (top-down) and horizontal actions.

First, enhance public health policy support for citizen science.—This vertical strategy reflects LHD representative views regarding the importance of buy-in and support from higher levels of government and funders. While the U.S. government has promoted use of citizen science at federal levels,[15,16] policies and coordination efforts to support its widespread use at regional, state, or local levels have not proliferated. Although this may reflect meaningful differences in disaster preparedness and response authority, there may be opportunities for complementary local efforts. Without such guidance, and associated resources, local agencies lack incentives for engaging with citizen science.

Second, invest in resources to support volunteer management.—This second vertical strategy reflects LHD staff availability constraints. While some LHDs manage or leverage existing volunteer units, such as MRCs and Community Emergency Response Teams (CERT),[17] several representatives noted that citizen science volunteers may need significant amounts of time to learn key scientific processes and measurement procedures. In addition, guidance is needed to clarify legal and ethical issues related to volunteer safety, human subjects protections, and state labor laws.

Third, develop research quality best practices.—This horizontal strategy reflects participant views that sound citizen science methods and transparency are important not just for ensuring data quality, but also for providing the foundation for strong collaborations. Project leaders highlighted the importance of making raw data and information about limitations accessible, ensuring methods and data quality practices were documented, employing validation checks and redundant data collection procedures, and discarding poor quality data.

Fourth, make investments to strengthen relationships among collaborating entities.—Given the integral role of academic and community groups in disaster citizen science, effective integration into PHEPRR systems would require strong relationships that leverage strengths of all partners. In this horizontal strategy, participants recommended targeting professional communities for education around citizen science, instituting open and transparent communication processes, and building infrastructure to facilitate data sharing and ensure interoperability between data systems used by collaborators.

Fifth, leverage and learn from existing resources.—This vertical and horizontal strategy reflects the considerable amount of vetted and accepted resources available on topics such as disaster responder volunteer training and management, volunteer safety, and citizen science trainings.[14] Two PHEP capabilities – volunteer management and responder safety and health – may be particularly instructive for developing best practices for managing disaster citizen science volunteers. In addition, project leaders noted opportunities to leverage resources such as existing disaster volunteer groups or online platforms for citizen science project management.[18]

Study limitations

Our assessment of disaster citizen science potential was based on respondent perceptions of outcomes and impacts rather than external evidence. Given response and desirability bias, participants may have mischaracterized challenges or overstated project impacts. In addition, LHD representatives may not have been familiar with all staff activities related to citizen science. Our participant sample overall skewed towards individuals with citizen science experience and positive perceptions of the field. Future research could include participants with a wider range of experiences or views on citizen science (negative and positive) to uncover additional challenges and facilitators.

Implications for Policy & Practice—Our findings indicate that disaster citizen science could support communities in building PHEP capabilities and community engagement to improve public trust. However, activities are not well integrated into traditional PHEPRR systems. LHDs may face particular constraints to implementing citizen science projects due to inadequate resources to support volunteer management, partnership development, and research quality. In addition, LHDs face challenges related to lack of institutional trust and acceptance of disaster citizen science. However, given the amount of PHEPRR-relevant activities occurring in academic and community sectors, and continued growth in the overall citizen science field, there is great opportunity for LHDs to collaborate with disaster citizen science researchers and practitioners. Specific strategies LHDs can implement to increase institutional acceptance and build PHEPRR capacity for disaster citizen science include enhancing public health policy support for citizen science; investing in resources to support volunteer management or data collection; developing best practices for ensuring research quality; strengthening relationships through investments in education, communications, and data sharing infrastructure; and adopting best practices from academic and community activities with PHEPRR relevance.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1.

Participant characteristics

Local health department representatives (*N*=18)			
LHD representative category	***N (%)***		
Emergency preparedness *	13 (72%)		
Executives (directors or administrators)	3 (17%)		
Epidemiology	1 (6%)		
Health education	1 (6%)		
Population size served	***N (%)***	***Census region***	***N (%)***
Small (< 50,000)	2 (11%)	West	4 (22%)
Medium (50,000 – 499,999)	9 (50%)	Midwest	7 (39%)
Large (≥ 500,000)	7 (39%)	South	6 (33%)
		Northeast	1 (6%)
Project leaders (*N*=31)			
Project leader category	***N (%)***	***Project focus***	***N (%)***
Academic/government	19 (61%)	United States	22 (71%)
Community	12 (39%)	International (non-U.S.)	4 (13%)
		Global	5 (16%)
Disaster **	***N***	***Citizen science model***	***N (%)***
Hurricanes	9	Contributory	14 (45%)
Chemical/oil contamination	8	Collaborative	5 (16%)
Hydrological risks	5	Collegial	12 (39%)
Algal blooms	4		
Climate change/sea level rise	4		
Earthquakes	3		
Radiation	2		
Disease outbreaks	2		
Tornadoes	1		
Volcanic eruptions	1		
Thought leaders (*N*=6)			
Thought leader category	***N (%)***	***Location***	***N (%)***
Academic/government	5 (83%)	United States	5 (83%)
Community	1 (17%)	International (non-U.S.)	1 (17%)

* Includes director, manager, coordinator, and analyst positions

** Numbers do not sum to 31 due to some individual projects that focused on multiple disasters

Table 2.

Public health emergency preparedness and response (PHEP) capabilities[1]

Capability	Description
Community preparedness	Ability to prepare for, withstand, and recover from public health incidents. Functions: determine health risks, strengthen community partnerships, coordinate and share information with partners, coordinate training and guidance to support community involvement
Community recovery	Ability to identify critical assets, facilities, and services within public health, health care, human services, and other sectors to guide and prioritize recovery operations. Functions: identify and monitor recovery needs, support recovery operations, implement corrective actions
Emergency operations coordination	Ability to coordinate with emergency management and to direct and support public health incidents by establishing a standardized, scalable system of oversight, organization, and supervision. Functions: conduct assessments to determine need for emergency operations, activate emergency operations, develop and maintain a response strategy, manage and sustain response, demobilize and evaluate emergency operations
Emergency public information and warning	Ability to develop, coordinate, and disseminate information, alerts, warnings, and notifications. Functions: establish and activate a public information system, facilitate public interaction and information exchange, issue warnings and alerts
Fatality management	Ability to coordinate with partner organizations and agencies to provide fatality management services. Functions: determine public health agency role in fatality management, identify and facilitate access to resources, assist in collection and dissemination of antemortem data, support provision of mental/behavioral health services, support fatality processing and storage operations
Information sharing	Ability to conduct multijurisdictional and multidisciplinary exchange of health-related information and situational awareness data. Functions: identify relevant stakeholders, develop guidance and systems for information exchange, exchange information to determine a common operating procedure
Mass care	Ability of public health agencies to coordinate with and support partners to address public health, health care, mental health, and human services needs. Functions: determine public health role in mass care operations, determine mass care health needs, coordinate public health, health care, and mental/behavioral health services, monitor mass care population health
Medical countermeasures	Ability to provide medical countermeasures (e.g., vaccines, antivirals) to targeted populations to prevent, mitigate, or treat the adverse health effects of a public health incident. Functions: determine medical countermeasure dispensing/administration strategies, receive medical countermeasures, activate medical countermeasure dispensing/administration operations, dispense/administer medical countermeasures to targeted population(s), report adverse events
Medical material management and distribution	Ability to acquire, manage, transport, and track medical material and recover and account for unused medical material. Functions: direct and activate medical materiel management and distribution, acquire medical materiel, distribute medical materiel, monitor medical materiel inventories and distribution operations, recover medical materiel and demobilize operations
Medical surge	Ability to provide adequate medical evaluation and care that exceed the limits of the normal medical infrastructure. Functions: assess nature and scope of the incident, support activation of medical surge, support jurisdictional surge operations, support demobilization of operations
Nonpharmaceutical interventions	Ability to implement actions that communities can take to help slow the spread of illness or reduce adverse impacts. Functions: engage partners and identify factors that impact nonpharmaceutical interventions, determine nonpharmaceutical interventions, implement nonpharmaceutical interventions, monitor nonpharmaceutical interventions
Public health laboratory testing	Ability to implement and perform methods to detect, characterize, and confirm public health threats. Functions: conduct laboratory testing and report results, enhance laboratory communications and coordination, support training and outreach
Public health surveillance and epidemiological investigation	Ability to create, maintain, support, and strengthen routine surveillance and detection systems and epidemiological investigation processes. Functions: conduct, support, or improve surveillance or public health investigations; recommend, monitor, and analyze mitigation actions
Responder safety and health	Ability to protect public health and emergency responders during pre-deployment, deployment, and post-deployment. Functions: identify, support, and monitor responder safety and health
Volunteer management	Ability to coordinate with emergency management and partner agencies to identify, recruit, register, verify, train, and engage volunteers to support the jurisdictional public health agency. Functions: recruit, train, and deploy volunteers and support their safety

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Table 3.

Alignment of citizen science activities with PHEP capabilities, based on authors' assessment

Project	Project description	Participant	Capability	Capability alignment area
Flint Water Study[1]	Community-academic partnership in Flint, MI, to test water for lead contamination	Academic	Community recovery	Implement corrective actions
			Public health surveillance	Conduct or support surveillance; Conduct investigations; Recommend mitigation actions
Graniteville Recovery and Chlorine Epidemiology (GRACE) project[2]	Community-based research to aid recovery of the Graniteville, SC community after a chlorine spill	Academic	Community recovery	Identify & monitor recovery needs; Support recovery operations; Implement corrective actions
			Volunteer management	Recruit, coordinate, and train volunteers
Participatory action research in post-Katrina New Orleans[3]	Participatory project to document experiences of women in post-Katrina, New Orleans	Academic	Community recovery	Identify & monitor recovery needs; Support recovery operations; Implement corrective actions
			Community preparedness	Coordinate training & guidance
Rural Alaska Monitoring Program (RAMP)[4]	Community-based monitoring in Alaska to monitor and detect climate-related threats	Academic	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
			Community recovery	Implement corrective actions
Local Environmental Observer Network (LEO) Network[5]	Network of local environmental observers in Alaska and topic experts that document environmental events in communities	Academic	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
Cyclone Center[6]	Database of cyclone data created through volunteer interpretations of satellite images	Academic	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
Mosquito Habitat Mapper[7]	Volunteer engagement to report and eliminate mosquito habitat and presence of larvae	Academic	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers

Seismographs in schools[8]	Global educational seismic network in schools that shares seismic data	Academic	Community preparedness	Coordinate training & guidance
PhotoVoice for disaster research in Hawaii[9]	Community-based research in Hawaii to assess vulnerabilities and capabilities and recommend disaster reduction strategies	Academic	Community preparedness	Determine risks to jurisdiction health
			Public health surveillance	Recommend mitigation actions
Community-based volcano monitoring[10]	Volunteer network (vigías) for volcano monitoring in Ecuador	Academic	Community preparedness	Determine risks to jurisdiction health; Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
El Reno Tornado Survey Project [11]	Crowdsourced observations of the 2013 El Reno tornado to improve tornado assessments	Academic	Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
Planetary Response Network[12]	Online damage assessments of disaster-affected areas around the globe by volunteers.	Academic	Community preparedness	Coordinate training & guidance
			Community recovery	Identify & monitor recovery needs
			Volunteer management	Recruit, coordinate, and train volunteers
URI Watershed Watch[13]	Volunteer engagement to collect water quality data throughout Rhode Island	Academic	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
Minna no data (Everyone's Data Site)[14]	Network of citizens' radioactivity measurement labs across Japan. Originally developed after Fukushima radiation disaster	Community	Community recovery	Identify & monitor recovery needs
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
MyCoast[15]	Volunteer engagement to contribute and analyze pictures and data in several U.S. states relating to coastal flooding and other events	Community	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
Oil Spill Tracker[16]	Mapping tool for the public to submit reports on Deepwater Horizon oil spill impacts	Community	Community recovery	Identify & monitor recovery needs
Community water testing after Hurricane Maria[17]	Volunteer water testing in Puerto Rico after Hurricane Maria	Community	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers

Monitoring oil contamination in Louisiana[18]	Development and evaluation of a citizen science oil spill monitoring training program	Community	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
King Tides Project International[19]	Volunteer engagement to document King Tides and sea level rise around the globe	Community	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
iWitness Pollution Map[20]	Mapping tool for reports of oil and chemical pollution and impacts. Originally developed for Deepwater Horizon oil spill reporting	Community	Community recovery[1]	Identify & monitor recovery needs
			Public health surveillance	Conduct or support surveillance;
Safecast[21]	Maps global radiation levels through a citizen sensor network. Originally developed for Fukushima radiation monitoring	Community	Community preparedness	Coordinate training & guidance; Determine risks to jurisdiction health
			Community recovery[1]	Identify & monitor recovery needs
			Volunteer management	Recruit, coordinate, and train volunteers
Tonawanda Coke Corporation pollution[22]	Community-led initiative to measure pollution emitted by a local foundry coke plant	Community	Public health surveillance	Conduct or support surveillance; Conduct investigations; Recommend mitigation actions
Beacon of Hope M.O.D.E.L. for disaster recovery[23]	Community framework for disaster recovery after Katrina, includes neighborhood mapping	Community	Community recovery	Identify & monitor recovery needs; Support recovery operations
Great Arizona Mosquito Hunt[24]	Engagement with schools and youth organizations to conduct oviposition trapping and enhance surveillance for *Aedes aegypti*	Government	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
Cyanobacteria Monitoring Collaborative[25]	Volunteer engagement to monitor cyanobacteria blooms and risk factors	Government	Community preparedness	Coordinate training & guidance
			Public health surveillance	Conduct or support surveillance; Recommend mitigation actions
			Volunteer management	Recruit, coordinate, and train volunteers
Use of MRC to conduct surveys*	Enlisting MRC volunteers to carry out damage assessments	Government	Community recovery	Identify & monitor recovery needs
Aliso Canyon gas leak[26]	LHD response to community-generated data on exposure and health effects from a gas leak	Government	Public health surveillance	Conduct or support surveillance; Conduct investigations; Recommend mitigation actions

Battery recycling plant emissions *	LHD response to community-generated data on contamination by battery recycling plants	Government	Public health surveillance	Conduct or support surveillance; Conduct investigations; Recommend mitigation actions
Community health assessment *	Engagement with university volunteers to collect data for community health assessments	Government	Community preparedness	Determine risks to jurisdiction health; Coordinate training & guidance
Crowdsourcing sources of Legionnaire's disease *	Volunteer engagement to analyze satellite imagery and find cooling towers	Government	Public health surveillance	Conduct or support surveillance; Conduct investigations; Recommend mitigation actions
Use of MRC to conduct surveys *	Enlisting MRC volunteers to carry out in-person community surveys	Government	Community preparedness	Determine risks to jurisdiction health
Needs assessment *	Volunteer engagement to conduct needs assessment after a tornado	Government	Community recovery	Identify & monitor recovery needs
Community Assessment for Public Health Emergency Response (CASPER) *	Training volunteers to perform data collection for CASPER assessments	Government	Community recovery	Identify & monitor recovery needs
Tick collection *	Volunteer engagement for tick surveillance	Government	Public health surveillance	Conduct or support surveillance

* Initiative as described by a respondent

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