CITIZEN SCIENCE:
THEORY AND PRACTICE

Community Seed Groups: Biological and Especially Social Investigations Can Support Crisis Response Capacity

SPECIAL COLLECTION: DISASTER, INFRASTRUCTURE, AND PARTICIPATORY KNOWLEDGE

CASE STUDIES

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ABSTRACT

The food system is comprised of biophysical and social processes affecting everyone, and food system citizen and community science offer opportunities for research, especially on unstudied aspects of that system, including responses to crises and disasters. We describe how community science work on food crop seeds responded to the crisis of the COVID-19 pandemic, and how this response built on the social investigations that are part of that ongoing work. To address a number of the crises of the Anthropocene, groups and individuals have been creating infrastructure supporting community-driven seed research and provision. Some organizations investigate community development of locally adapted crops, and introduction of novel materials for testing in new environments, as well as alternative social organization and processes supportive of this research and aligned with their values. Looking at examples of two active, United States–based, community seed organizations, represented by two of the co-authors, we outline the values and theoretical grounding of this work, and how responding to the acute crisis of the COVID-19 pandemic has challenged these organizations to rapidly develop seed distribution work in ways consistent with their values and missions. Meeting these immediate needs has meant temporarily pivoting from the longer-term evolutionary processes of their community science biological investigations; still, existing social investigations remained relevant and useful in their pandemic work. The effectiveness of this crisis response provides an example of explicitly values-driven research, and indicates the importance of recognizing the implicit social investigations of community science that sometimes experiment with alternative approaches to organizing society to achieve both immediate results, and longer term, prosocial change.

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INTRODUCTION

The food system is comprised of biophysical and social processes that intimately affect every human, and food system citizen[1] and community science (CCS) offer opportunities for research, especially on unstudied or overlooked aspects of that system (Kimura and Kinchy 2020), including responses to crises and disasters. We describe two community seed science and action organizations represented by two coauthors, and how those projects are responding to the COVID-19 crisis by building directly on their existing social investigations and the associated infrastructures they have created. Based on these examples, and the growing evidence that human survival and flourishing require equity and justice (e.g., Pelling and Garschagen 2019), we argue that the social investigations occurring in some community science projects deserve as much attention as their biophysical investigations. This case study is based on our experiences, observations, and discussions, taking stock after a pandemic year. If no citation is provided, statements regarding the organizations are the words of the representative coauthor.

The Anthropocene has intensified the interconnection between the social and biophysical challenges facing humanity locally and globally (e.g., Kelly, Thombs, and Jorgenson 2021), and has increased the need to expand engagement in science. Some see the recent growth in CCS as a necessary part of our response to the Anthropocene's extensive, intertwined social and biophysical challenges (Pandya 2014).

We take a broad view of CCS, working from a definition of science as a process typically including many of the following characteristics: It is systematic, requires empirical observations as evidence, forms testable explanations, is open to scrutiny, and is non-authoritarian (Rutherford and Ahlgren 1991). Compared with conventional and citizen science, community science lies closer to Irwin's idea of the democratization of science through greater public participation and power in the process (Irwin 1995). A key characteristic of community science is that different questions may be asked, perspectives taken, and epistemic and values diversity included, not only about biophysical variables, but also about related social processes (e.g., Corburn 2005). Some community science investigations may include minimal contributions by professional scientists, and be regarded as incipient research compared with conventional, formal science. In the examples described here, both biological and social investigations are similar to observational studies, which in community seed research are appropriate exploratory inquiries into complex field contexts.

Many community science projects emphasize biophysical data about the issue at hand, more than data and analyses about the social processes that make the biophysical investigation possible (e.g., Macey et al. 2014). This is understandable given the urgency of many projects, such as those investigating environmental injustice in heavily impacted communities—groups defined spatially or recognizing shared identity, e.g., based on experience, ethnicity, race, gender. Still, there are exceptions, and some projects are parallel investigations of biophysical and social variables, even if the latter may be considered methods rather than a part of the research. These social investigations often test the organization and process of research, reflecting values regarding the generation of knowledge, indeed, what even qualifies as knowledge, and proposing alternative social relations. For example, the social processes and relationships in the community-based participatory research project Gardenroots were described in detail (Ramirez-Andreotta et al. 2015). The challenges and importance of steps used by formal researchers and community members in the research co-creation process are outlined, including decision-making, and how changes in understanding and expectations were addressed. The ICBO (Independent Community Based Organizations) work of the CCS project Celebrate Urban Birds focuses on "collectively us(ing ICBOs') strengths and expertise to delve deeper and more meaningfully into research that represents (their) communities' perspectives" and the process of building trust in research driven and controlled by communities themselves. That work uses grounded theory, with inductive investigations arising from community priorities, questions, and expertise.

The community science seed work we describe centers around a microevolutionary process that results from the interaction between plants, the biophysical environment, and the social organization of practice animated by values. Thus it's a useful example for starting to explore the relationship between biophysical and social components of community science, including in response to crises.

Richmond Grows Seed Lending Library (RGSLL) and the Experimental Farm Network (EFN) are two small, very different community crop seed organizations, sharing an emphasis on developing the biological material and social organization they believe necessary to improve our food system. In different ways, each has been prominent among community seed groups in responding to the COVID-19 pandemic, one focused on a city (RGSLL), the other on northern North America (EFN), but both having wider impacts.

We identify chronic crises in the food system that RGSLL and EFN address through their empirical work, and the theories and values underpinning that work. We briefly describe RGSLL and EFN (and its Cooperative Gardens Commission [CGC] project), their biological and social investigations, the infrastructures built to accomplish these,

and their responses to the COVID-19 pandemic. To explicitly include social investigations in community science, we suggest framing these as we do biophysical investigations: as testable hypotheses with attendant assumptions, and appropriate indicators for testing them. Finally, we consider lessons learned from our case study for future community science that can nimbly and effectively respond to disasters and crises, while simultaneously striving to create prosocial alternatives—those intentionally benefiting others and society at large—for the future.

WHAT PROBLEMS ARE COMMUNITY SEED ORGANIZATIONS ADDRESSING?

Aid practitioners distinguish between disasters "triggered by a specific event in time and place, such as an earthquake" and crises that are "periods where there is disruption, confusion, and suffering that can go on for many months as the situation evolves" (Da Silva 2020). Recently, a review of 209 CCS projects that prepare for, or respond to, disasters found only 19% involved the public in aspects beyond data collection (Chari et al. 2019); that is, very few were community science projects. In contrast, environmental justice CCS projects often involve community science to address chronic crises that have been ongoing for years, or centuries, as was found in a small survey of projects in northern California (Ballard and Dixon 2013). In community seed work, practitioners are responding to multiple crises, both chronic and acute.

CHRONIC CRISES

Community seed work in the United States (US) is a response to the food system's contribution to multiple chronic crises. The oldest crisis being addressed—racial and social inequity—permeates society, including the food system (e.g., Horst and Marion 2019), with the greatest negative impact on the most vulnerable. For example, the disproportionate severity of food insecurity and noncommunicable diseases in low-wealth areas and communities of color, is in part a result of lack of access to fresh fruits and vegetables (Belanger et al. 2020).

Loss of crop diversity is a chronic crisis that threatens the stability of food production, the food system's capacity to mitigate or adapt to changes, and our ability to maintain socioculturally significant crops and foods. Community seed activism in the US is a direct response to this crisis, and includes a biological focus on saving varietal diversity, locally selected varieties, and less-used species (Helicke 2015; Soleri 2017).

The food system, including seed provision, contributes to and is affected by the anthropogenic climate crisis (Clark et al. 2020) that is producing trends in environments and society requiring novel responses (Soleri, Cleveland, and Smith 2019). Examples include changing growing environments and the crops that may be grown (e.g., Parker and Abatzoglou 2016), and increasing atmospheric greenhouse gas concentrations that negatively impact food quality and public health (Weyant et al. 2018). These chronic crises are now overlain by the acute crisis of the COVID-19 pandemic, exacerbating risk and social and material inequities (Egede and Walker 2020).

AN ACUTE CRISIS

The COVID-19 pandemic is an acute global crisis that has affected food systems. The industrial food system in the US continues to function for those with resources, but many earning lower wages have lost employment (Gezici and Ozay 2020). Unemployment is likely the reason that in the US from 2018 to 2020 the number of food insecure people increased from 35.2 to 50 million, and among children from 10.7 to 17 million (Feeding America 2021). Food insecurity and poor food quality contribute to the pre-existing pandemic in communities of color of noncommunicable diseases linked to above-average COVID-19 morbidity and mortality (Belanger et al. 2020).

As the pandemic's magnitude became evident in the US in late February 2020, demand increased rapidly for basic goods, like food, and the means to produce food, including seeds. The timing coincided with the spring planting season, creating intense pressure on commercial seed suppliers. For example, seed orders at Baker Creek, an heirloom seed company, increased threefold to more than 3,000 daily (K McFarland, Baker Creek, personal communication, 9 October 2020). Overwhelmed with orders, Baker Creek had to close its phone lines and online seed catalog, as did numerous other garden seed sources. Some community seed organizations shifted quickly from ongoing work to distributing seeds to the public for growing food for themselves and those without access to fresh produce or garden space.

WHAT VALUES AND THEORIES UNDERPIN SOME UNITED STATES COMMUNITY SEED ORGANIZATIONS?

The values and theories underpinning community science can differ from those of more conventional research, making community science more subject to critique and questioning (e.g., Nature 2015; Soleri et al. 2016). Yet an implicit and rarely questioned value in conventional science is that the research product contribute to individual and institutional prestige (Schekman 2013). RGSLL and EFN explicitly state their values: Their work should contribute to social equity, biodiversity and environmental protection, and that their investigations are a part of the change they aspire to. Table 1 outlines key theories for RGSLL and EFN,

THEORY	THEORY REFLECTED IN COMMUNITY SEED WORK	REFERENCES (THEORY/ APPLICATION)
Biological diversity expands response capacity	Development of locally appropriate, adapted seeds Participatory plant breeding Diversity conservation Risk mitigation	Falconer and MacKay 1996/ Ceccarelli 1996; Letourneau et al. 2011
Knowledge diversity is necessary for strong objectivity and justice	Valuing experiential as well as formal knowledge Broad participation, diversity of experiences Grassroots investigations and action Community science	Freire 1970; Harding 1995/ Tengö et al. 2014
Common property resource management can contribute to prosocial goals	Reformulation of the management of shared resources Seeds as products of commoning process Respect for community-defined commons limits, e.g., Native American enclosure of Native American seed	Ostrom and Hess 2010/Euler 2018; Montenegro de Wit 2019; Sievers-Glotzbach et al. 2020
	Open-source, non-proprietary seeds that may be widely used and shared Reduced barriers to broader, equitable access to and use of seeds	OSSI 2021; SELC 2014
Cooperative behaviors support social adaptation, justice	Mutual aid as social processes that transform power dynamics in society	Kropotkin 1902/Firth 2020; MADR 2021; Spade 2020

Table 1 Key theories for the work of some community seed organizations in the United States.

reflecting the interconnections between the biological and social components of their work (see Supplemental File 1).

WHAT WAS THE PRE-PANDEMIC SEED WORK OF THE RICHMOND GROWS SEED LENDING LIBRARY AND THE EXPERIMENTAL FARM NETWORK?

We briefly describe the community science biological and social investigations RGSLL and EFN were conducting before the pandemic, indicating the hypotheses being tested, associated assumptions, and relevant indicators. In both organizations, these investigations are ongoing.

RICHMOND GROWS SEED LENDING LIBRARY

Seed libraries, community seed banks, and seed swaps are community-driven responses to perceived shortcomings and negative biological and social impacts of large-scale, commercial seed systems (Soleri 2017; Vernooy, Shrestha, and Sthapit 2015). These institutions typically offer free seeds, and support biodiversity, more equitable and broader seed access, and food security and sovereignty.

Richmond Grows Seed Lending Library was started in 2010 by RN and a colleague and is located in the public library in Richmond, CA. Since establishment, RGSLL has been maintained by RN with a steering committee of 7 to 10 people. For RN, starting RGSLL was a values-driven decision because seed saving is foundational practically for being able to feed people, and also for restructuring the food system to support biodiversity, and to move away from a proprietary model toward one based on seed and food commons. RGSLL's mission includes both biological and social objectives (Table 2).

Like many seed libraries, RGSLL's day-to-day functioning is similar to traditional book lending. Inside the library, RGSLL maintains repurposed card catalogs with packets of free seeds organized by ease of seed saving. Unlike book borrowing, there is no requirement for seed returns, but like other seed libraries, RGSLL suggests patrons save seeds for continued planting, and return a small portion of those to RGSLL to sustain seed stocks.

Biological investigation

The opening of RGSLL initiated a biological investigation exploring diversity conservation through decentralized, participatory maintenance and selection in gardens by gardeners in Richmond and surrounding areas. As part of this, RGSLL hypothesizes that its work contributes to greater crop diversity and adaptation than would be present without those efforts through the following mechanisms: growing varieties that are not among conventional, commercial garden seed offerings; creating and maintaining distinct local varieties and/or genotypes; and enabling more people to garden and cultivate these crops. There is evidence that home or community gardens can be reservoirs of diversity not otherwise available. For example, a study in England that reviewed genetic diversity of 171 heritage varieties of six vegetable species maintained by a home gardeners' seed network found those varieties to contain "a unique and broad spectrum of crop genetic diversity… not represented in more formal genebanks" (Preston et al. 2019).

When it first opened, RGSLL obtained seed donations, primarily from small seed companies. Through time it

METRIC	DETAILS
Year founded	2010
Mission statement	"Our Mission is to increase the capacity of our community to feed itself wholesome food by being an accessible and free source of locally adapted plant seeds, supplied and cultivated by and for Richmond area residents. Richmond Grows celebrates biodiversity through the time-honored tradition of seed saving, nurtures locally-adapted plant varieties, and fosters community resilience, self-reliance, and a culture of sharing. We celebrate our human diversity through outreach and inclusion. Richmond Grows strives to fulfill its mission by focusing on two activities: 1. To establish and grow a seed library—a depository of seeds held in trust for the members of that library—available to all Richmond residents; 2. To provide information, instruction and education about sustainable organic gardening."
Website	http://www.richmondgrowsseeds.org/
Organizational structure	Community-based organization overseen by volunteers; fiscally sponsored project of a 501(c)3 nonprofit, Urban Tilth
2020 COVID-19 RESPONSE	
Project	Tiny Free Seed Libraries, Richmond, CA
People	~60, seed preparation, distribution network
Seeds	20,000 packets*
Other resources, activities	Seed Saving in a Time of Crisis classes (5); Absolute Beginners Gardening classes (6); gardening listserv for class participants and open to community to share gardening tips and resources; webpages for Absolute Beginner Gardeners, in English and Spanish; Grow a Row Program to involve more community members in growing seeds for community; how to save seeds brochure, in English and Spanish. Late 2020—early 2021: hosted cuttings give-away of figs, grapes, pomegranates, currants; distributed > 400 cuttings; perennial Purple Tree Collard cuttings give-away in collaboration with Urban Tilth and City of Richmond

Table 2 Richmond Grows Seed Lending Library.

*Packets were a) one species, or b) a mix of garden species; both included what RGSLL thought a household would plant in a season, plus a little extra.
Source (RGSLL 2021).

increasingly focused on locally grown and selected varieties and prioritized ones with cultural significance in the community. By 2019, all seeds RGSLL offered were locally grown—approximately 150 edible varieties, including a small number originating in the Richmond area.

RGSLL's biological investigation uses processes relevant to the seed library, its users, and the larger community, and like all science, includes assumptions. Their hypothesis is being tested through the establishment of RGSLL, and its use. Specific indicators can include the types (genus, species, variety) of seeds offered, the number of seeds borrowed, and the proportion of RGSLL seeds that are locally unique and grown in the community. Biological assumptions include: different named varieties represent phenotypic and genotypic differences, and so can be metrics of diversity; local cultivation creates adaptation.

Social investigation

Interconnected with its investigation of diversity and local adaptation in garden crop seeds, RGSLL is implicitly conducting a social investigation to explore and strengthen its goal of a "culture of sharing." It is creating an alternative infrastructure that contrasts with the dominant paradigm of commercial garden seed production and access, and is supporting similar organizations and their growth locally and globally (Seed Library Network 2021; Soleri 2017). That infrastructure includes RGSLL itself, the website and the many free resources offered there, the social processes it uses (like the local seed growers network), and the sociopolitical environment for seed sharing.

For example, at a national level, RGSLL was a central contributor to the successful effort, started in 2014, to protect seed sharing by distinguishing seed libraries from commercial seed sources, thereby exempting seed libraries from state and national seed quality regulations that are prohibitive for them (SELC 2014); as a result thus far, four states have passed seed sharing protection laws.

RGSLL and other seed libraries are testing the hypothesis that a community can use a voluntary library model, self-sustained by seed borrowers, to maintain some or most of its own free, locally produced garden seed supply. If this model works, its impact on inequity and barriers to seed access, and on biological adaptation could be investigated. In the global north this is a relatively unexplored hypothesis, especially at the community scale, except for significant Native American initiatives.

Providing free, accessible garden seeds is a central focus for many seed libraries, which are small, low- to no-budget organizations. The ideal of having borrowers themselves replenish seed stocks has not occurred in most cases; in California the proportion of borrowers returning seeds was 0–28%, averaging 6% (Soleri 2017). Still, the goals of developing local adaptation and conserving diversity may be met even without high rates of seed return, if seed continues circulating directly among gardeners, and if return rates increase as borrowers become familiar with community-based resource management. These questions have not yet been investigated.

Even if the hypothesis of seed self-sufficiency based on returns to seed libraries is currently rejected, RGSLL is testing another hypothesis that an alternative social organization and process can maintain a local seed supply. This is a small, open, network of volunteer community seed stewards (e.g., gardeners, small-scale farmers, a nonprofit with an educational garden space) ready to increase seed stocks as needed by RGSLL to ensure continuing community access to free, locally grown varieties. This includes online growout sheets for matching community seed stewards with seeds needing replenishment, and for reporting basic details of the growout, including any notable plant characteristics. This work was participants' first experience taking direct responsibility for stewarding a community resource. Meaningful indicators for this hypothesis could include sustained provision of seeds desired by Richmond gardeners; broadening community engagement; and evidence of spillover of similarly community-focused social processes into other activities based on participation in RGSLL. This hypothesis assumes community seed stewards will continue to volunteer.

RGSLL's biological and social investigations have been driven primarily by RN, and a major focus is expanding and decentralizing these processes and supportive infrastructure to make RGSLL a more durable community resource.

EXPERIMENTAL FARM NETWORK

The nonprofit EFN was founded in 2013 to facilitate open access to participatory plant breeding (PPB) and diversity exploration (Table 3). EFN frames this work within a larger effort to support agriculture that will "fight global climate change, preserve the natural environment, and ensure food security for humanity into the distant future," alongside commitment to "social, racial, and economic justice." The

METRIC	DETAILS
Year founded	2013
Mission statement	"To accelerate innovation in sustainable agriculture by facilitating unprecedented collaboration on research and the free sharing of resources. • Create an open, easy-to-use online platform for PPB and other agricultural research. • Connect researchers, plant breeders, and scientists with an army of volunteer growers. • Spread knowledge, seeds, and other resources to all those who may take advantage of them. • Build a cohesive network of people and organizations committed to working cooperatively over the long-term. • Develop new crops and growing systems capable of mitigating or even reversing the effects of global climate change."
Websites	https://www.experimentalfarmnetwork.org/ http://www.efnseeds.com
Organizational structure	Cooperatively-run 501(c)3 nonprofit, and fiscal sponsor of four additional projects: Palestine Heirloom Seed Library (seed saving project led by Palestinian food justice activist Vivien Sansour); Fair-Amount Food Forest (project to install a permanent food forest in Philadelphia's Fairmount Park); Munsee Three Sisters Medicinal Farm (project led by the Turtle Clan Chief of the Ramapough Lenape people in north-central New Jersey); and CGC.
2020 COVID-19 RESPONSE	
Project	Cooperative Gardens Commission (CGC)
CGC mission statement	"The CGC is composed of hundreds of volunteers from across North America working as a collective to facilitate the conscientious sharing of resources—including seeds, soil, equipment, labor, land, and knowledge—and build solidarity across traditional divides. We are farmers, gardeners, activists, and organizers. We believe increasing local food production can help build community power and resilience"
CGC website	https://www.coopgardens.org/
People	500+
Seeds	1,200 lb in 2020
Other resources, activities	Educational resources for gardeners, resource-sharing map, more than seven active working groups, bi-monthly public organizing/informational conference calls

Table 3 Experimental Farm Network Cooperative.

Sources: (CGC 2021) and https://www.experimentalfarmnetwork.org/.

impetus and continuity for EFN come primarily from the two cofounder colleagues, NK and Dusty Hinz, with occasional input from an executive board and EFN researchers. The EFN online platform provides the opportunity for anyone to crowdsource assistance with PPB and crop diversity experimentation.

Biological investigation

Like RGSLL, EFN's biological investigations focus on adaptation and diversity, but with larger spatial coverage. One area of research is enhancing planted diversity at species, variety, and genotypic levels. EFN's work tests the hypothesis that through their projects greater crop diversity can be conserved and deployed. A related hypothesis is that this diversity provides adaptation by contributing to more climate-friendly agriculture, temporally and spatially expanded food-production capacity, and reduced input requirements. An active member-started project reflecting those hypotheses is the Perennial Dividing Onion Diversification project to increase multiplier-type onions (*Allium cepa* L. var. *aggregatum* G. Don), which asks participants to grow and save seed from these onions for the project. Pre- and post-harvest observations and descriptions of "notable strains" are also requested. Saving and cultivating seeds, the product of cross pollination, introduces new genetic combinations into that crop's regional gene pool that would not otherwise be available because it is typically clonally propagated. Subsequent clonal propagation of strains with desired characteristics for a location creates novel, and potentially more locally appropriate, varieties for gardeners. Many EFN projects explore under-utilized germplasm, including much accessed from the United States Department of Agriculture's (USDA's) collection. A focus is perennial crops that might be improved for food production in specific growing environments, such as cold hardy *Opuntia* cactus, perennial sorghum, and others.

As with RGSLL, indicators appropriate for EFN's hypotheses include species, varieties, and genotypes released through EFN projects, with the assumption that different names represent phenotypic and genetic variation. Other possible indicators are changes in spatial and temporal cropping area, or changes in inputs and carbon sequestration attributable to these releases, compared with production without them.

Social investigation

EFN was established following NK's involvement with Occupy Sandy (OS), the mutual aid hurricane recovery collective founded by former Occupy Wall Street organizers. OS demonstrated to NK the unequal impacts of a climate-related disaster, and disproportionate suffering in economically marginalized communities. OS also influenced the development of EFN by showing that volunteers organized by amateurs could provide effective relief in an acute crisis, even as established, professionally run disaster relief organizations failed to meet the scope of Sandy's impacts, despite decades of experience (Ambinder and Jennings 2013). EFN attempts to replicate the successes of OS in the field of climate change–responsive plant breeding. The larger purpose is to transform the food system, "build a better world,...put the brakes on neoliberal capitalist exploitation of the planet and its inhabitants." EFN is investigating a social organization that it hypothesizes will be more effective for achieving the biological and agricultural goals of conserving and increasing crop diversity and local adaptation, while also capable of achieving the social goals of justice, equity, and participation in the food system.

EFN is implicitly testing the hypothesis that a free, open, cooperatively-run online platform can improve the pace, breadth, and participation in crop conservation and improvement through open PPB and diversity exploration, conducted by non-professional volunteers who self-organize into projects. It assumes this social organization would be at least partially responsible for benefits derived from EFN projects. Relevant indicators for this hypothesis could include novel strategies and outcomes resulting from this process; individual learning and change as a result of EFN participation; and evidence of spillover of this form of social organization into other activities from participation in EFN projects.

EFN's platform is basic and functional, allowing projects to define their own parameters and methods. Membership is free, open, and required to become a participant in any of the 28 current projects. Members wishing to start a project create a researcher profile, which may include a CV, website, and description of work, although only an email and mailing address are necessary. To create a project, a researcher completes a form describing the work and what participants are asked to do. The project is then posted and available for other EFN members to join. Through this process, anyone can launch a project and work with members who join it, providing assistance with the work, their own knowledge, and sometimes extended geographic and environmental coverage not otherwise available.

HOW HAVE THE RICHMOND GROWS SEED LENDING LIBRARY AND THE EXPERIMENTAL FARM NETWORK RESPONDED TO THE CRISIS OF COVID-19?

The pandemic quickly revealed vulnerabilities in the US food system as millions lost employment, and food insecurity rose; by June 2020, 43% of low-income households in

the US were food insecure (Wolfson and Leung 2020). With the pandemic, nationwide demand for garden seed rose precipitously. Seed companies struggled to expand their seed order–processing infrastructure, with some simply resigned to being unable to respond. Native American organizations and tribes distributed seeds and other food-system support to tribal communities in some locations (Hoover 2020). Some public entities such as extension services in a few states organized to distribute free seeds or garden kits, as did some philanthropic organizations. Nonetheless, demand remained high.

Early in the crisis, RGSLL, EFN, and other seed organizations recognized the implications for food security in many communities and quickly reoriented their work in response, focusing on garden seed distribution, with seeds that meet their free and open-source criteria.

Formal "humanitarian seed aid" in response to disasters and crises dates to the mid-1970s, with efficacy varying, depending on timing, form, attention to local context, and the larger goals of donors (Sperling et al. 2020: 1). Some seed aid has created biological and social challenges for gardeners and farmers, for example, when seeds don't go to those who need them, are for crops or varieties people don't know or like, are environmentally inappropriate, introduce a proprietary or financial constraint, or have a marketing objective. For example, in response to COVID-19, Bayer-Monsanto—one of the four largest global seed companies—provided smallholder farmers in the global south with "care packages" containing proprietary seeds and crop-protection products (herbicide), with PPE "in some packages." Both RGSLL and EFN were cognizant of these potential shortcomings as they moved to rapidly make seeds available in spring 2020.

RICHMOND GROWS SEED LENDING LIBRARY

The Richmond Public Library was closed by the pandemic in March 2020, but RGSLL quickly pivoted to making seeds available in Richmond through Tiny Free Seed Libraries (TFSLs) (RGSLL 2021) (Figure 1). These small boxes or other displays were placed in cooperating businesses and organizations, or were hung on fences near community sites such as parks and gardens. In all, 13 sites hosted TFSLs in Richmond in 2020 (Figure 2). Because of the anticipated need, and the ease of working with larger quantities of seed to meet that need, RGSLL did not use their own, locally grown seeds for the 2020 distribution. RN purchased $2,000 worth of seasonally appropriate seed in bulk from small seed companies.

RGSLL turned to the social infrastructure it had built, including many of the same practices and the small network of volunteers, but also expanded the call for assistance to new networks such as Nextdoor, Urban Tilth, the Watershed Project, The Latina Center, and local environmental activist groups serving different populations. The response was positive; 60 people offered to help, compared with the 7 to 10 involved pre-pandemic, and they were more diverse,

Figure 1 Tiny Free Seed Libraries (TFSLs) established by Richmond Grows Seed Lending Library (RGSLL) in Richmond, CA in response to the COVID-19 crisis, 2020.

TFSL on the street (*left*); TFSL in worker-cooperative bike shop Rich City Rides (RCR) with Najari Smith, RCR Founder and Executive Director (*top right*); TFSL, the Arlington Market, Richmond (*lower right*). Used with permission of subjects, and photographer, Rebecca Newburn.

Figure 2 Locations of Tiny Free Seed Libraries (TFSLs) established by Richmond Grows Seed Lending Library (RGSLL) in Richmond, CA in response to the COVID-19 crisis, 2020.

including Latinx, Japanese, Cantonese, and Nepali volunteers, in contrast to the predominantly white pre-pandemic volunteers. The City of Richmond noticed, and in September 2020 started partnering with RGSLL as a seed distributor.

Infrastructural support was also expanded for the TFSLs. RGSLL created detailed videos about how to package seeds safely, how to start TFSLs and organize them for minimal cross-contamination and risk, as well as offered tutorials and classes about crisis gardening and seed saving. These resources were used to establish TFSLs in other locations; for example, RGSLL's "Safe seed packing" video was viewed 638 times between April 2020 and June 2021.

Building on existing and new practices and networks, RGSLL, actively led by RN, responded quickly, distributing approximately 20,000 free seed packets (Table 2) in Richmond from March through December 2020.

COOPERATIVE GARDENS COMMISSION

In March 2020, NK and colleagues established what would become the CGC as a project of EFN (Table 3). Through EFN, and other networks, including the organic and heirloom seed movement, small seed company leaders, and former Occupy Wall Street and OS participants, the CGC grew rapidly. For example, more than 130 people participated in CGC's first organizing conference call, and more than 160 participated in the second call, three days later.

The CGC, "a grassroots organizing collective…(that is) open, transparent, non-hierarchical, and committed to consensus-based decision-making" (CGC 2021), was created using the infrastructure developed by OS and EFN: the EFN platform; social networks of Occupy, EFN, and others; EFN social media; tools developed for Occupy including InterOccupy, an organization hosting massive, open, horizontal organizing calls (using MaestroConference); and the practices for conducting those calls for information-sharing and consensus decision-making. Using InterOccupy, CGC operates primarily through bi-monthly organization-wide online organizing calls. Through these calls, CGC working groups (WGs) were formed according to the interests of participants. The most

active WGs have been: accountability, anti-oppression and allyship, BIPOC, fundraising, outreach, policy, and seed distribution. Many WGs are developing strategies for longer-term actions to address chronic crises, including through food and agriculture policies, land sharing, and a reparations roadmap. These calls, and CGC's other work, give special attention to process, including opportunities for anyone to speak, and for ideas to be openly vetted and included in a public-meeting-notes Google doc. This openness and patience are intended to encourage broad participation, and are often participants' first experience with consensus decision-making, along with practices such as declaring pronouns, and land acknowledgements.

Seed distribution has been the primary focus of CGC, with seed donations solicited from organic, small, regional seed companies familiar to EFN organizers. Like RGSLL, the urgency of the pandemic crisis pressed CGC to acquire seed where available, with less specific attention to local adaptation in favor of providing gardeners with something to plant. Still, CGC attempted to offer seeds that were environmentally and culturally appropriate from donations they received.

Similar to RGSLL, CGC experienced great interest from the public wanting to help; more than 2,000 people filled out EFN's initial volunteer and resource-sharing form. More than 1,000 people have signed up for the bi-monthly organizing conference calls. By the end of the 2020 planting season, CGC had 257 seed hubs—distribution centers receiving seed from CGC—in 41 states (CGC 2021). A seed hub application form was the basis for prioritizing sites serving communities historically marginalized and in urgent need. Applicants were also asked to identify culturally significant crops in their communities. Many hubs worked with local community-based organizations capable of identifying households and individuals wanting seeds and able to plant immediately. In 2020, an estimated 12,000 gardens received a share of approximately 1,200 lb of seeds (Figure 3).

Additionally, CGC's website features a resource-sharing map on which individuals can place themselves and list the resources they have available to share, including seeds, tools, land, volunteer labor, and knowledge or mentorship. As of March 2021, more than 300 individuals and hubs were on the map (Figure 4).

Figure 3 Cooperative Gardens Commission seed packaging, spring 2020. CGC Instagram.

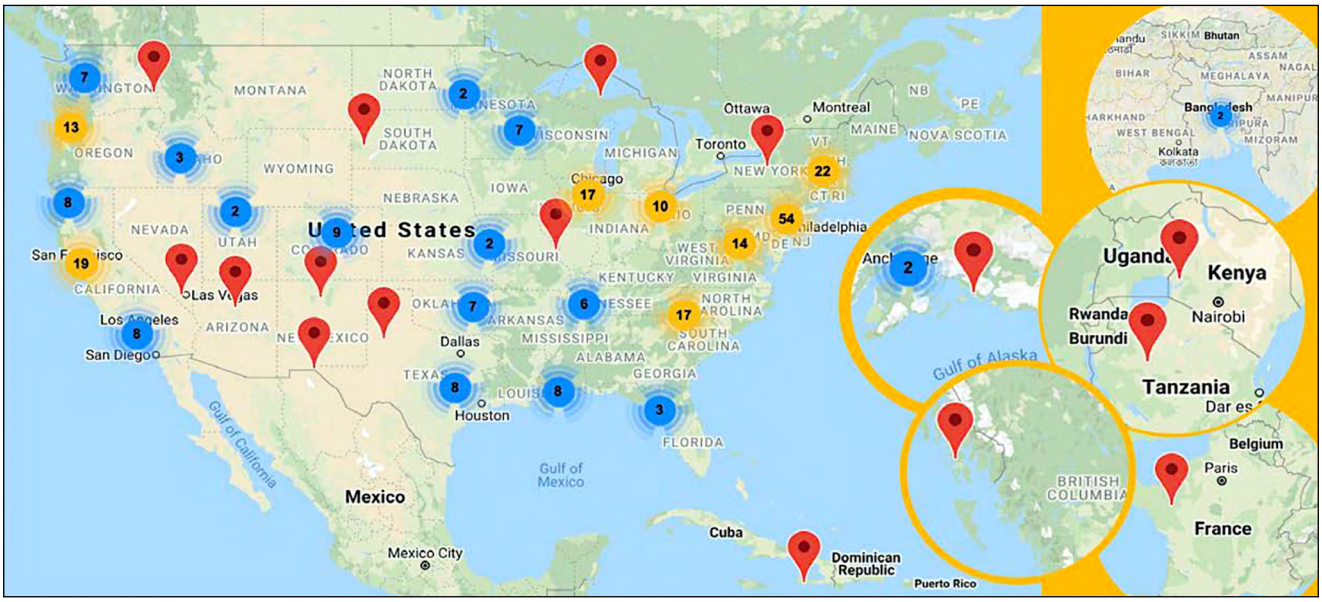

Figure 4 Cooperative Gardens Commission resource-sharing map, 2020. https://www.coopgardens.org/.

CONCLUSION

Our review of RGSLL's and EFN's seed work suggests a number of lessons. First, community-driven science can be scientific investigations that openly reflect community, and sometimes non-conventional values. This may occur not through bias or other anti-scientific practices as some scientists have worried (Nature 2015), but rather through community scientists investigating social organization and processes interrelated with their biophysical investigations. These social investigations may explore alternative approaches to problem solving.

Second, in responding to acute crises, the biophysical investigations of a community science project may become secondary as other priorities and opportunities arise. The urgency of the COVID-19 crisis has meant that seed distribution has taken precedence over RGSLL's and EFN's pre-pandemic biological investigations into developing diverse, locally appropriate, crop populations. Both organizations intend to continue that work when the urgency of this crisis eases, and see this experience as evidence of the need for the pre-COVID work for stronger community seed institutions that provide sufficient locally appropriate seeds to meet needs in future crises.

Third, social investigations established before an acute crisis can support the crisis response. Although their biological work changed, RGSLL and EFN used the social infrastructure they were already investigating before the pandemic, including networks, and forms of social organization and process, to support their rapid response to the COVID-19 crisis in a manner consistent with the values and theories foundational to those organizations.

Fourth, the impetus for, and continuity of, investigations of alternative social practices may come from one or a few individuals, including in crises. We speculate that because they are relatively novel in the US, many people are unaware of, and/or inexperienced with these practices until introduced to them and their supportive infrastructures by experienced individuals.

In response to the COVID-19 pandemic, journalist Naomi Klein quoted Milton Friedman, neoliberal economist and proponent of "disaster capitalism," whereby in the immediate wake of disasters and crises, neoliberal policies that are often socially oppressive are forced upon a population that is collectively in shock: "Only a crisis—actual or perceived—produces real change. When that crisis occurs, the actions that are taken depend on the ideas that are lying around. That, I believe, is our basic function: to develop alternatives to existing policies, to keep them alive and available until the politically impossible becomes politically inevitable" (Friedman 2020) cited in (Klein 2021). The pandemic response work of community science seed organizations like RGSLL and EFN/CGC confirm Friedman's observation, while offering alternatives antithetical to his.

Both RGSLL and EFN/CGC relied on their pre-existing commitment to grassroots cooperation for shared well-being as they pivoted to respond to the acute COVID-19 crisis. Their responses included continuing to experiment with voluntary, open, community-based processes that enabled them to provide material support, but also demonstrate a prosocial pathway to problem solving, drawing on values and theories relevant to their missions. While disaster capitalism benefits from crisis-induced social vulnerability, public engagement in RGSLL's and CGC's pandemic work appears to benefit from "catastrophe compassion" (Zaki 2020), in which experiences of shared social identity and empathetic emotional connection are

powerful motivators to prosocial action that has been documented across countries, populations, and crises.

As demonstrated in this case study, the social investigations implicit in some community science projects are useful resources, and could inform the structure of projects moving forward in an increasingly crisis-prone world. Identifying hypotheses, assumptions, and appropriate indicators can be a helpful first step in making these investigations visible, and doing so will become more feasible as practitioners and scholars build relevant theories and practice. For example, community science projects will be able to test experience and theory about commoning (Euler 2018; Sievers-Glotzbach et al. 2020) and mutual aid (Spade 2020), as appropriate. Although not always the primary focus in community science, the social investigations of the community seed science described here were existing alternatives "lying around" that provided a framework for effective crisis response that harnessed catastrophe compassion. These projects delivered material support while engaging the public in experimentation with approaches to problem-solving and alternative infrastructures that were novel for many participants. For this reason, we suggest that there may be an important opportunity for community science to recognize and more systematically explore the social investigations being undertaken in tandem with the biophysical ones. These investigations are more than methods for achieving biophysical goals, they may offer pathways to more just and effective responses to Anthropocene crises.

NOTE

1 Our use of the term citizen here is out of convention, but we, along with many others, urge reconsideration and replacement of that term with one that is more open and less fraught with current political implications.

SUPPLEMENTARY FILE

The supplementary file for this article can be found as follows:

- **Supplemental File 1.** Further details and references regarding theories of the community seed organizations. DOI: https://doi.org/10.5334/cstp.406.s1

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

DS raised the idea for this article with RN and NK while attending virtual pandemic-response meetings of RGSLL and CGC starting March 2020. We met virtually to discuss the idea and produced the abstract via joint work on a Google document. Based on existing practice and published statements of the projects, and discussions among all coauthors, we identified the crises those projects respond to, and the theories underpinning their work. The initial outline and rough draft were written by DS, after which we met virtually, and we interacted on the manuscript through a Google document. The second and third authors are listed in alphabetical order and contributed equally.

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