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How Do We Build Community Resilience to Disasters in a Changing Climate? A review of interventions to improve and measure public health outcomes in the Northeastern United States

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Table of Contents

List of Tables

List of Figures

Executive Summary

Climate change-related natural disasters, including wildfires and extreme weather events, such as intense storms, floods, and heatwaves, are increasing in frequency and intensity (USGCRP, 2018). These events are already profoundly affecting human health in the Northeastern United States and globally (Ghazali et al., 2018; IPCC, 2018; USGCRP, 2018), challenging the ability of communities to prepare, respond, and recover. This paper examines the peer-reviewed literature on community resilience interventions and metrics that may apply to the Northeastern region of the United States.

The overarching goal of this document is to inform local public health practitioners and planners about the availability of evidence-based strategies to strengthen and measure community resilience to climate change-related disasters. We were interested in metrics that were derived from publicly available data sources and that were developed for use by communities at a local scale, and accessible to more modestly resourced municipalities and county health agencies. We searched the literature for papers describing the strategies employed to increase community resilience and the metrics used to measure resilience as an outcome of those strategies. Specifically, we looked for those strategies or interventions that aimed to meet the U.S. Centers for Disease Control's standards for building community resilience as part of reaching the United States' National Preparedness Goal.

Our search revealed 205 articles on community resilience in the Northeast: of those, five described evidence-based strategies. This paper discusses the five selected strategies, their applicability at a local public health level, and the metrics used to measure the extent to which community resilience had been strengthened. We also share two relevant case studies: 1) in Los Angeles County, to demonstrate the use of metrics in a multi-year community resilience intervention; and 2) in New Hampshire, to show how an intervention emerged through the development of a climate and health adaptation plan. We recommend the COAST project, COPEWELL Rubric for self-assessment, and Ready CDC intervention as examples of strategies that could be adapted by any community engaged in building community resilience.

Introduction

Climate change-related natural disasters, including wildfires and extreme weather events, such as intense storms, floods, and heatwaves, are increasing in frequency and intensity in the Northeastern United States and globally (Ghazali et al., 2018; IPCC, 2018; USGCRP, 2018). These events challenge the ability of communities to prepare, respond, and recover, resulting in impacts to both human health and community resilience (Ghazali et al., 2018; IPCC, 2018). Natural disasters and extreme weather events affect the public's physical or mental health through injury and other trauma, vector-borne diseases, heat-related illness, and illness resulting from reduced air and water quality (Ebi et al., 2018; Petkova et al., 2015). Natural disasters impact the overall functioning of a community by overwhelming available healthcare and disaster response resources (March, 2002).

Interventions designed to reduce the health impacts of natural disasters may focus on the individual, family, or community to build and enhance community resilience (Keller, et al., 2013; Marinucci et al., 2014). Here, we define community as a group of individuals who are linked together by shared geographical space, situations, or interests, and collectively engage in action (MacQueen et al., 2001; Sharifi, 2016).

We discuss how building community resilience aligns with the United States' National Preparedness Goal for reducing risks to human health and for recovering quickly from disasters. We review various definitions of community resilience. We explore how community resilience can be built or enhanced and review the metrics that have been used to measure the extent to which the interventions strengthened resilience. We then discuss the parameters and results of our review that addressed two critical gaps in the literature: 1) what strategies or interventions have been implemented to build or enhance community resilience against climate change-related natural disasters in the Northeast, and 2) what metrics were used to measure community resilience as an outcome of those strategies or interventions? We conclude with recommendations for public health practitioners engaged in building community resilience.

A severe 2013 storm/flood event destroyed several roads in the small town of Gilsum, NH, affecting access to the Fire Department (right) that also served as an emergency shelter.
Photo by Janine Marr.

National Preparedness Goal and Standards for Community Resilience

Community resilience at the local level is situated within and influenced by national-level policy and actions. This national context is important for understanding the focus of this paper on local community resilience action. In 2003, President George W. Bush issued Homeland Security Presidential Directive-8: National Preparedness, which directed the Secretary of the Department of Homeland Security (DHS) to develop a national all-hazards preparedness goal for the nation to prevent, respond to, and recover from emergencies in the United States (Department of Homeland Security, 2007). The directive was replaced in 2011 by Presidential Policy Directive/PPD-8: National Preparedness which directed the Secretary of DHS to develop a national preparedness goal in which all U.S. citizens and organizations shared responsibility (White House, 2011). This new directive downscaled the focus on local and individual preparedness leadership and action, making community-level resilience initiatives even more important.

The NPG was conceptualized as five interconnected missions to: 1) prevent terrorism; 2) protect against hazards; 3) mitigate loss of life and property; 4) respond quickly to human needs after a disaster; and 5) recover in a timely and productive manner (FEMA, 2015). Mitigation included hazard identification, risk assessment, vulnerability reduction, public warning systems, and community resilience (Figure 1). The U.S. Centers for Disease Control and Prevention (CDC) created national standards for the public health components of the NPG; these standards were designed to improve public health emergency preparedness and response capabilities at both the state and local levels (Centers for Disease Control and Prevention, 2019a). The national standards consisted of six domains, including incident and information management, countermeasures and mitigation, surge management, biosurveillance, and community resilience (CDC, 2019a). The CDC standards divided community resilience into two tiers: 1) community preparedness; and 2) community recovery (Figure 1).

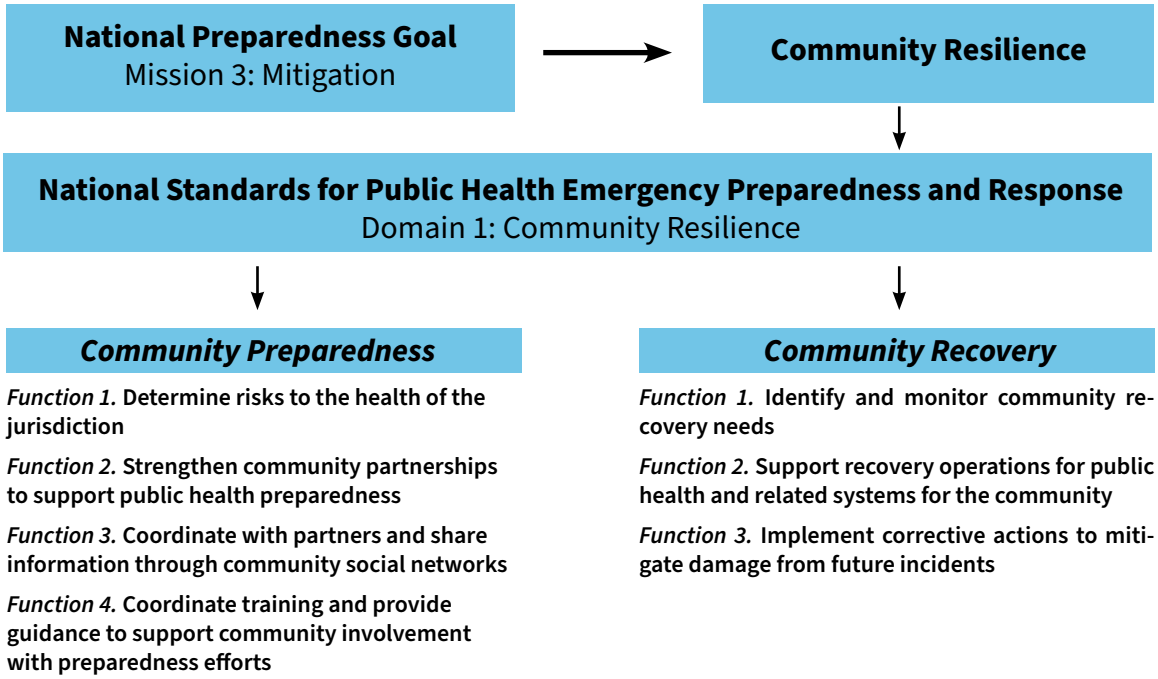


Figure 1. Community Resilience, although affected by all five missions, is named explicitly within Mission 3 of the National Preparedness Goal (FEMA, 2015, p. 11), and Domain 1 of the National Standards for Public Health Emergency Preparedness and Response. (Centers for Disease Control and Prevention. 2019a, p. 176).

The National Preparedness Goal (NPG) is to create "a secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk" (FEMA, 2011, p.1.).

The national preparedness standards were revised in 2018. The former definition of at-risk populations—"children, those with disabilities and others who have access and functional needs, and populations with limited English proficiency" (FEMA, 2011, p, 17)—became individuals who have "access and functional needs that may be disproportionately impacted by an incident or event" (CDC, 2019a, p. 11). In addition, program evaluation measures were no longer included. The revised standards encouraged state and local public health agencies to devise their own strategies to assess the impact of their programs on increasing public health preparedness and response through enhanced community resilience. This state and local level assessment imperative is a primary focus of – and motivation for – this review.

What Is Community Resilience and Why Is It Important?

There is no commonly accepted working definition of community resilience (Chandra et al., 2010; Patel et al., 2017). Community resilience is defined differently by organizations engaged in: 1) disaster risk reduction; 2) public health; and 3) national health security (Chandra et al., 2010; Djalante & Thomalla, 2011). Definitions typically focus on the strengths of a community and how those strengths can be used to improve and sustain health (Chuang et al., 2018; Plough et al., 2013). We present definitions of community resilience from these three perspectives as they emphasize three important community resilience outcomes: maintaining basic functions; using community assets; and becoming self-reliant.

First responders knocked door to door to warn and rescue at-risk residents in Alstead, NH, in 2005, as riverside homes and businesses were swept away from the floodwaters caused by a severe rain event.
Photo by Janine Marr.

Community resilience and disaster risk reduction

In the field of disaster risk reduction, community resilience is defined as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (United Nations Office for Disaster Risk Reduction, 2015, p.26).

From the disaster risk reduction perspective, a resilient community is one that has the ability to: 1) prepare for natural threats; 2) reduce vulnerability by decreasing disaster risks; 3) absorb and recover from disasters; 4) adapt to changing conditions; and 5) sustain the health of the community (Djalante & Thomalla, 2011; Goodykoontz & Taylor, 2015; Summers et al., 2019).

Community resilience and public health

Public health defines community health resilience as "the ability of a community to use its assets to strengthen public health and healthcare systems and to improve the community's physical, behavioral, and social health to withstand, adapt to, and recover from adversity." (U.S. Department of Health and Human Services, 2015, Community Resilience section, para. 1).

Community resilience is measured by "the ability of people, businesses, governments, nonprofit groups, and faith-based organizations to work together to create systems that can withstand, adapt to, and recover from a public health emergency" (CDC, 2020a, Community Health Resilience, para. 2). The CDC, through its Public Health 3.0 initiative, has taken a community-level approach to public health that engages multiple community partners from both public and private sectors. The initiative is based on the premise

Vermont's community resilience made headlines after Tropical Storm Irene in 2011.

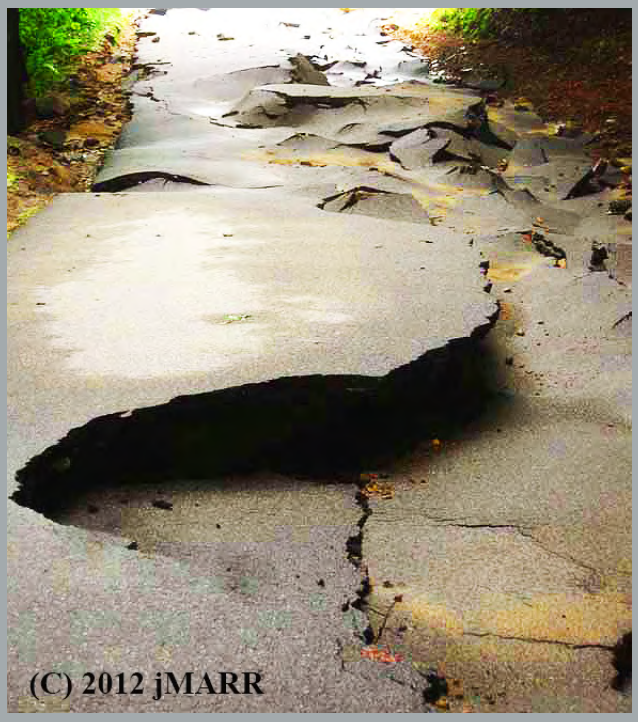
that local communities have the ability to improve their own public health and wellbeing, equity, and resilience (DeSalvo, 2017).that local communities have the ability to improve their own public health and wellbeing, equity, and resilience (DeSalvo, 2017).

Community resilience and national health security

> *At the level of national health security, community resilience is defined as a set of skills and behaviors already in place before a disaster, that can be strengthened through education and training, to enable communities to become more self-reliant in response to public health emergencies when external assistance may be delayed or limited (U.S. Department of Health and Human Services, 2010).*

The national health security strategy for the United States has been attained when "the Nation and its people are prepared for, protected from, and resilient in the face of health threats or incidents with potentially negative health consequences" (U.S. Department of Health and Human Services., 2010, p. 5).

Each of the three definitions are similar in that they address the means by which a community can respond to and recover from a disaster. However, definitions differ in terms of perspective. Disaster risk reduction aims to reduce risks and maintain basic structures and functions within a community. A disaster risk reduction perspective is helpful for city planners focused on infrastructure issues. The public health perspective utilizes community assets to improve physical and mental health at the population level (rather than individual), and is the focus of interest in this review of the literature. National health security defines the essence of community resilience—to prepare communities to be self-sufficient during disaster events while



May, 2012, road damage in southwest NH from storm surge runoff that destroyed culverts and roads and marooned residents for several days.

Photo by Janine Marr.

Based on these definitions, community resilience is both an outcome and a process (Chuang et al., 2018; Djalante & Thomalla, 2011; Eisenman et al., 2014; Pfefferbaum et al., 2015). As an outcome, community resilience is an attribute that is attained through strategies or interventions designed to: 1) enhance community preparedness for public health incidents; or 2) identify critical assets within the public health, human services, environmental health, and emergency management sectors that are needed for community recovery (CDC, 2019a; Community and Regional Resilience Institute, 2013). A resilient community has the ability to prevent, respond or adapt to, and recover from incidents that impact human health in a timely manner and at a level of functioning that supports equity and well-being (Haarsaker, 2020).

As an ongoing and dynamic process, community resilience involves a focus on building social connectedness and improving the everyday health and wellness of a community over time (Chandra et al., 2011; Sharifi, 2016; U.S. Department of Health and Human Services, 2015).

These definitions of community resilience provide a foundation for understanding how to strengthen and measure resilience. We explore those questions in the following sections.

> ***"Planning—that's what it's all about. You can't wait until it's happening to get the word out."***
> ***— [Social Service Agency Staff Member at Monadnock Region BRACE Stakeholder Meeting, 2018]***

How Is Community Resilience Built or Enhanced?

Interventions to improve community resilience are often designed differently than actions that enhance individual resilience (Figure 2.) Community resilience focuses on networking community members and organizations within and beyond the community to support the health and wellness needs of the whole community, including at-risk populations. Individual resilience interventions address the wellness needs of an individual (Chandra et al., 2011).

Enhancing Individual Resilience

- Promote individual wellbeing and mental health for routine and emergency situations
- Utilize personal strengths and social support of family, friends, neighbors, and the faith community to strengthen a self-image of resilience, rather than the helpless victim
- Develop coping strategies to withstand stress and return to a state of mental health wellbeing
- Ask for help and seek resources
- Build and maintain family and social connectedness
- Expand self-reliance skills including first aid, emergency kits, family evacuation and reunification plans to increase individual capacity to shelter in place

Enhancing Community Resilience

- Promote community physical, behavioral, and social health and wellness for routine and emergency situations
- Use community assets to strengthen public health and healthcare systems to improve a community's physical, behavioral, and social health
- Develop and strengthen accessible public health and social service networks and resources to withstand disaster impacts and enhance community recovery
- Engage at-risk individuals and programs that serve them
- Build social connectedness between community members
- Expand communication and collaboration between social service, community, academia, business, and faith-based organizations for pre-disaster response and recovery plans

Figure 2. A comparison of individual and community resilience characteristics (U.S. Department of Health and Human Services, 2015, 2017, 2018.

> ***"What convinced me to leave my house was a boat came by my window."***
> ***— [Local Resident at Monadnock Region BRACE Stakeholder Meeting, 2018]***

Community resilience and vulnerable populations. Identifying vulnerable populations is central to the goal of strengthening the overall resilience of a community. Populations are vulnerable to climate-related hazards when they: 1) are exposed to a perceived hazard or threat; 2) are sensitive to its physical or health impacts; and 3) lack the capacity to withstand, resist, or adapt (Ebi et al., 2018; Manangan et al., 2015; Martin, 2015). Vulnerable populations lack adaptive capacity when they live in isolation from the community as a whole. Social isolation has been correlated with post-disaster mortality; populations that are socially isolated from support systems, participation in community organizations, or access to municipal and governmental institutions in daily life are more likely to experience health impacts or death post-disaster (Martin, 2015). Vulnerable populations may include: older adults; children; communities of color; lower-income neighborhoods; individuals or families with physical or medical challenges, including chronic diseases and addictions; homeless, tourist, or community-living populations; people with limited English literacy or

education; and people with no access to transportation, healthcare, technology, or citizen status (Ebi et al., 2018; Martin, 2015).

The vulnerability of a population to climate change-related natural hazards is dependent upon both hazard type and location (Cutter et al., 2008). Climate projections indicate that vulnerable populations in the Northeast will experience increased extreme heat and precipitation events. Local planners are encouraged to include heat resilience strategies in their climate and health adaptation plans, particularly in rural areas that are more physically isolated, and that have higher poverty rates and natural resource-dependent economies (Winter et al., 2019). At the neighborhood scale, a municipality that is vulnerable to flooding and extreme precipitation events may have a hilltop residential area that is less vulnerable than the surrounding community. The hilltop community may be more resilient due to its lower physical exposure, greater access to financial resources and generators that reduce its sensitivity to power losses, and stronger connections with social networks or health resources that increase its adaptive capacity (Johansen et al., 2017). In contrast, a nearby low-lying area may be more vulnerable to flooding and erosion. Planners can use a number of vulnerability assessment tools to identify where populations are at greatest risk for health impacts based on exposure, sensitivity, and adaptive capacity (Manangan et al., 2015).

One vulnerability assessment tool is the CDC's social vulnerability index (SVI), which uses easily available U.S. Census data, such as income, special needs, age, inability to understand English, and access to housing and transportation, to assist public health officials in determining county sections that may be most vulnerable to disasters (Agency for Toxic Substances and Disease Registry (ATSDR), 2018). The New Hampshire Department of Health and Human Services (DHHS) adapted the CDC's SVI to identify towns with populations at increased risk for environmental or public health hazards (Holt, 2014; NH Environmental Health Tracking Program, 2018) (Figure 3).

Researchers used the NH SVI to determine the effects of climate change on New Hampshire's coastal wetlands, such as inundation and flooding, and in turn, their impacts on human health (Kirshen et al., 2018). Community resilience is built or enhanced by engaging the community, including vulnerable populations, in the process of learning to identify and mitigate the risks associated with climate-related natural disasters. Tools and frameworks are available to identify risks, vulnerable populations, and the steps needed to reach resilience as an outcome. Despite the availability of

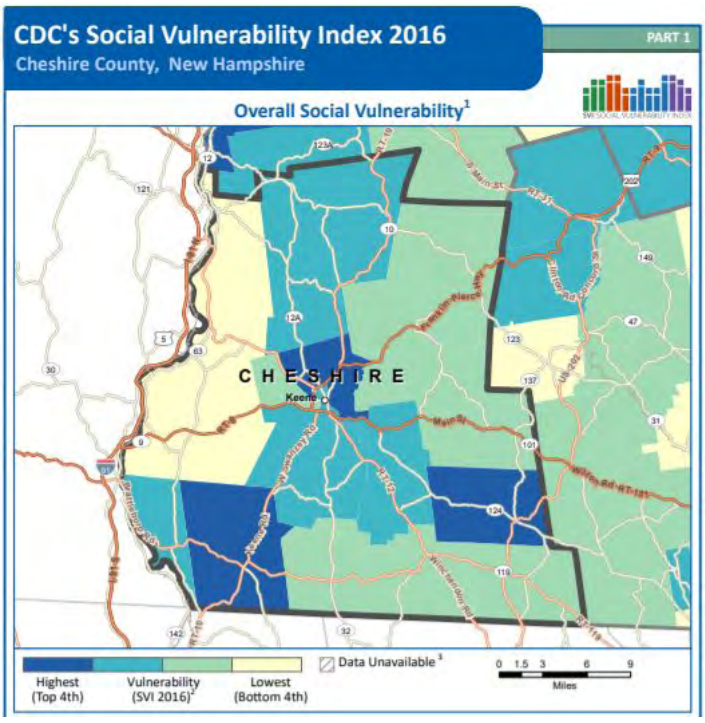


Figure 3. An example of the CDC's social vulnerability index in southwest NH. Regions in the darkest blue are most vulnerable to disasters.
From: ATSDR (2018).

frameworks for guiding community resilience initiatives, few have been incorporated into interventions and evaluated (Eisenman et al., 2014). The question we pose is, how do we know the methods used to build or enhance community resilience are effective and can be applied in other contexts? To answer that question, we must also ask: how do we measure community resilience? That is the question we address next.

How is Community Resilience Measured?

Tools used to measure community resilience may assess community resilience as a whole, or focus on one indicator, such as community partnerships. These tools also range from a generalized multiple-hazard application to a specific hazard or community, such as flood zones along the coast (Johansen, et al., 2017). Tools use both indicators and metrics to measure resilience. Indicators are the elements of community resilience that are being measured, such as community engagement or community partnerships. Metrics are the units of measurement or comparison, such as communication, transportation, and utilities; these metrics vary with the scope and scale of an intervention (Christiansen, et al., 2018). We present examples of metrics used for community disaster resilience, with a focus on public health, in Table 1.

Table 1

Sample Metrics to Measure Community Resilience to Disasters

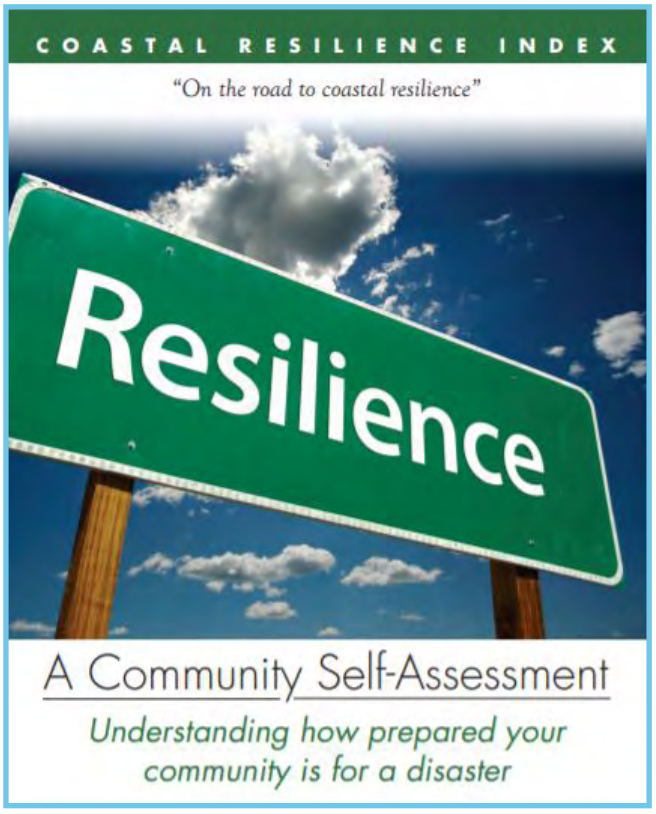
Resilience Indicator	Focus Area	Metric
Process	Disaster and Recovery Management	• Number of hazard mitigation, emergency preparedness and recovery public meetings held and number of public participants • Number of organizations involved in recovery and disaster management planning processes
Social	Communities and Social Services	• Social services and community healthcare facilities available • Organizations available to offer disaster-related medical or mental health support for post-traumatic stress disorder, depression, etc. • Number of physicians
Social	Households	• Percent of population residing in temporary housing units • Median and mean household income
Social	Population Characteristics	• Households without access to a car • Population over age 65 • Population disabled

Note. Dwyer & Horney. (2014). Validating Indicators of Disaster Recovery with Qualitative Research. Revised Focus Area and Metrics from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4323412/figure/d35e406/

Metrics may identify additional needs of a community, as with a vulnerability index; track the process of an intervention, as with a focus group during the intervention; or assess the outcomes of the intervention, as with a post-intervention survey (Leiter & Pringle, 2018). Without metrics, how can we know if an intervention was successful at building community resilience?

A review of 36 community resilience assessment tools revealed a variety of metrics to measure preparation, recovery, and adaptation, including: emergency planning and services; knowledge and access to information; health and well-being; social connectedness; and infrastructure (Sharifi, 2016). Data were collected in the form of interviews and surveys, and based on analytical tools, including scorecards and indices. Six percent of the 36 tools used primary data only, which included interviews and surveys from key informants; 28% of the tools relied on secondary data only, including U.S. census data, historical records, and statistical data from municipal and non-profit organizations; and 44% of the assessment tools incorporated both primary and secondary data (Sharifi, 2016). Of the 36 tools reviewed, 24 had been tested with one or more communities.

Assessment tools, by design, have either a top-down or bottom-up approach. Tools with a generalized, top-down approach are developed by external organizations, separate from the community being measured, and may be adaptable to a variety of hazards or locations. Tools with a localized, bottom-up approach are developed through active engagement with the community and adapted to the specific hazards for that community (National Research Council, 2015). The downside to a generalized assessment tool is that it may not capture the characteristics of a community



The Coastal Resilience Index (CRI) is an example of an assessment tool that can be applied by local planners to determine if their community has low, medium, or high disaster resilience.
From: masgc.org.

that reflect its resilience or vulnerability. The downside to a localized assessment tool is that it may not easily be used to compare one community with another.

Formative and summative metrics. Metrics can be categorized into two types: formative and summative. Formative metrics provide feedback during an intervention or process of designing an intervention, whereas summative metrics assess the results of the intervention (Caye, 2012; Sharifi, 2016). For example, a formative metric, such as vulnerability, is measured with the SVI for a focus group discussion on how to increase the resilience or adaptive capacity of a

particular population during the intervention. In contrast, a summative metric, such as a post-intervention survey, assesses the outcomes of the intervention, with a focus on improving the intervention for future use.

To answer our question of how community resilience is measured, we conducted a review of the literature. Our goal was to understand:

1) what strategies or interventions have been implemented to build or enhance community resilience and how resilience was strengthened;
2) what metrics were used to measure community resilience as an outcome of those strategies or interventions; and
3) which interventions could be applied at a local level, and with modest resources, to achieve the U.S. National Preparedness Goal?

We address these questions, based on the results of our literature review, in the following section. We conclude with recommendations of evidence-based community resilience interventions, tools, and metrics that can be applied at the local level to meet the CDC standards of the National Preparedness Goal.

Methods

We conducted a review of the published literature to answer our questions about community resilience interventions in the Northeastern United States and the metrics used to measure their success. Our second goal was to identify which interventions and methods of data collection could be applied at the local level by public health and other practitioners.

Selection Criteria

We used a multiple-step process for this literature review. We began by exploring the peer-reviewed literature on community resilience interventions and metrics available through Academic Search Complete, Cochrane Library, PubMed, and Web of Science databases. We searched for studies that:

1) evaluated interventions designed to increase community resilience and reduce public health impacts of climate change and associated natural disasters; and 2) employed metrics to measure community resilience, either as a baseline assessment of the community's resilience and adaptive capacity, or as a result of the intervention. We limited our search to studies in English conducted in the Northeastern and Mid-Atlantic United States. There were no restrictions on the year of publication.

Keyword search phrases included: (community resilience) AND (evidence-based interventions OR measures OR metrics OR assessment) AND (severe or extreme weather OR natural hazards or disasters) AND (community recovery OR adaptation strategies OR hazard mitigation) (Table 2). "Public health impacts" generated too few studies so the term was removed from the search.

> ***"Will interventions be incorporated into the hazard mitigation plans? Doing so would add to channels of city response and communication."***
>
> ***— [Local Government Staff Member at Monadnock Region BRACE Stakeholder Meeting, 2018]***

Table 2

Initial Keyword Search Results for Community Resilience Literature 5/10/20

Database	Total articles for terms "community resilience AND extreme or severe weather or natural hazard or disaster AND community recovery or adaptation strategies or hazard mitigation"	Total articles for "community resilience AND evidence-based intervention or measures or metrics or assessment AND extreme or severe weather or natural hazard or disaster AND community recovery or adaptation strategies or hazard mitigation"	Total articles for "community resilience AND evidence-based intervention or measures or metrics or assessment AND extreme or severe weather or natural hazard or disaster AND community recovery or adaptation strategies or hazard mitigation AND public health impacts"
Academic Search Complete	37	14	0
Cochrane Library	2	2	0
PubMed	383	174	59
Web of Science	1194	460	3
Total	1616	650	62

Note. Above totals reflect all articles, prior to removing duplicates, non-US, and non-English studies.

The search produced 650 publications. Using the selection criteria described previously, we reviewed the title and abstract of each publication. We excluded duplicate articles, conference papers or books, articles about research outside the Northeastern United States, non-English articles, and publications unrelated to human health and community resilience. The remaining 205 publications were selected for this review (Table 3).

Table 3

Results of Database Search for Community Resilience Interventions and Metrics

Database	Initial Search	Duplicates/Unmet Criteria	Full Texts to Review
Academic Search Complete	14	6	8
Cochrane Library	2	2	0
PubMed	174	119	55
Web of Science	460	318	142
Total	650	455	205

Next, we read each article that met the above criteria and analyzed it for information pertaining to the hazard, the intervention, and the metrics used to measure resilience.

Each article was analyzed for the following information:

1) type of climate and/or health impact;
2) target population or community and location;
3) the method used (intervention, tool development or trial, research study);
4) the formative metrics used to measure community resilience;
5) the summative metrics, or health-related outcomes;
6) data sources;
7) if the data was publicly available (local sources or available online);
8) which of the CDC's seven national standards were met;
9) author(s) and year.

We present our results in the next section.

Results

The literature review yielded 24 articles that demonstrated a range of interventions and metrics related to community resilience in the Northeast and Mid-Atlantic states (see Appendix A). Three articles described health and community resilience interventions; eight reported on the development and piloting of community resilience tools; and 13 discussed studies of public health and community resilience. The articles explored a variety of climate and health impacts; however, 50% of the articles examined hurricane resilience, specifically to Superstorm Sandy. Five articles addressed the impacts of winter and coastal storms, floods, drought, and heatwaves.

Data Sources for All Articles Reviewed

In the 24 articles we fully reviewed, data used to measure resilience were collected using qualitative and quantitative methods in a variety of formats, and from a range of publicly available national, county, and municipal sources (see Figure 4). The most commonly used data sources were project participants and online U.S. Census data. Half of the 24 projects used participant surveys and interviews to gather data on population demographics and community resilience indicators. Eleven studies accessed online U.S. Census data sources for demographics and population distribution. Three projects accessed county-level U.S. Census data and shapefiles for creating maps.

Each article described the use of an assessment tool; however, because the focus of this paper is on applied interventions and tools with metrics to measure community resilience, we eliminated 19 research articles from this review because the tools and interventions described were conceptual and had not been applied.

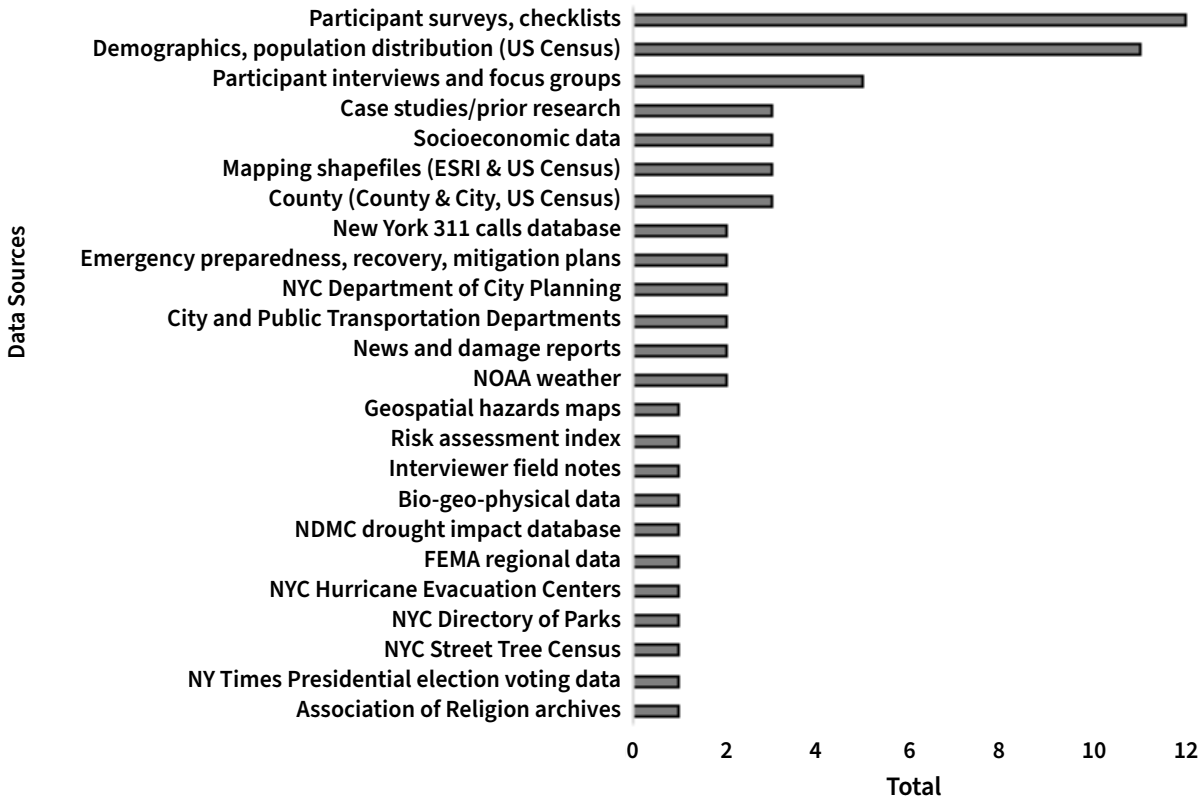


Figure 4. **Data sources for interventions, community resilience tools, and research studies.**

Articles Meeting the Selection Criteria

Five articles met all of our selection criteria. Three articles described intervention frameworks and two reported on tools: 1) COAST Project mental health intervention; 2) Resilience and Coping for the Healthcare Community (RCHC) mental health intervention; 3) Ready CDC community resilience intervention; 4) COPEWELL Rubric social capital and community engagement assessment tool; and 5) Garden State community resilience tool. All five interventions or tools were implemented and evaluated (Table 4).

Table 4

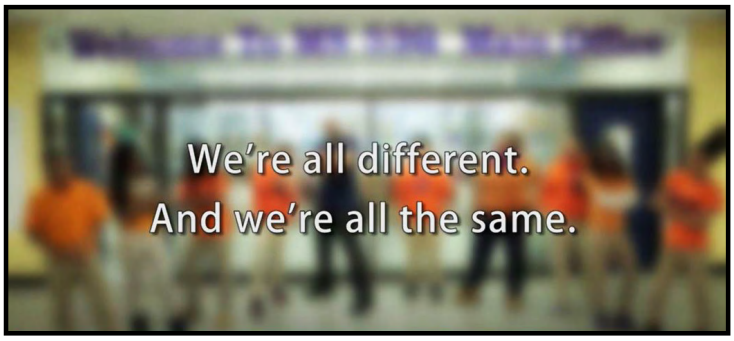
Five Evaluated Community Resilience Interventons and Metrics with Associated Climate and Health Impacts in the Northeast and Mid-Atlantic States

Climate and Health Focus	Target Population and Location	Method	Formative Metrics (Unit Measured)	Summative Metrics (Health-Related Outcomes)	Data Sources	Data Available Locally?	2011 CDC National Standards	Source
Hurricane recovery (Superstorm Sandy) and community resilience	Students, parents, teachers in Far Rockaway and Long Beach, NY	Mental health intervention	Coping skills, behavioral risk and stress reduction, PTSD, depression	Youth PTSD and depression reduced; model adopted for Long Beach's curriculum; students created YouTube PSA.	Pre and post survey of students, parents, educators, and school-based providers participating in COAST Project	✓	All of the above	D'Amico et al. (2017)
Hurricane recovery (Superstorm Sandy) and mental health resilience	Community mental health workers in NY & NJ	Mental health intervention	Self-efficacy, stress response, coping strategies, demographics	RCHC intervention increased perceived knowledge and decreased stress scores.	Participant surveys and interviews before, during, and after intervention	✓	b, c, d, f	Powell & Yuma-Guerrero (2016)
Disaster preparedness	CDC staff in GA, WV and CO	Community resilience intervention	Preparedness attitudes and behaviors	Intervention increased emergency preparedness knowledge and community resilience.	Ready CDC evaluation and pre-post survey	✓	a, c, d, g	Thomas et al. (2018)
Community disaster resilience	Community partners in Chester County, PA and community members in Coatesville, PA	Social capital and community engagement tool development, pilot	Participation in community groups, trust, connectedness	Piloted COPEWELL Rubric's social capital domain; user's guide needed for community self-assessment.	Participant knowledge and experience on social capital and resilience	✓	a, b, c, e	Schoch-Spana et al. (2019)
Hurricane recovery (Superstorm Sandy) and community resilience	Community in Hudson County, NJ	Community resilience tool	Pre-event planning, municipal operations, demographics	Piloted Garden State model; community in need of Continuity of Operations Plan for flooding, storm surge, and sea level rise impacts.	Emergency plans; geospatial mapping of flooding, sea level rise, and storm surge; risk assessment index; in-person discussions	✓	a, b, c, e, f, g	Bowman & Newman (2017)

*Notes. Abbreviations include: CDC: Centers for Disease Control and Prevention; RCHC: Resilience and Coping for the Healthcare Community; PTSD: post-traumatic stress disorder; PSA: public service announcement; COAST: Creating Optimism After Sandy Trauma; COPEWELL: Composite of Post-Event Well-being model. * CDC National Standards: a) determining health risks in a community; b) coordinating and strengthening community partnerships; c) sharing information; d) providing preparedness trainings; e) identifying recovery needs; f) supporting recovery operations; and g) implementing actions to mitigate future adverse effects from future incidents.*

COAST Project mental health intervention

The COAST mental health intervention enhanced community resilience for individuals and groups in two separate New York communities impacted by Superstorm Sandy. The project addressed the mental health needs of vulnerable youth, parents, and teachers in two school communities through: a) increased local partnerships with a mental health agency and b) the incorporation of resilience messages within the school culture (D'Amico et al., 2017). Education, support, and services were provided to build student resilience, educate and support parents and teachers, and address the needs of at-risk youth. Metrics that assessed student engagement and increased capacity to cope with stress and trauma included: a) student, parent, and teacher feedback; b) student volunteerism in art and media projects; and c) participation in discussion groups and school organizations during the intervention.



Public service announcement by COAST participants: https://www.youtube.com/watch?v=v0ZpvqFUIjY.
Used with permission.

Tools used to assess post-traumatic stress disorder (PTSD) and depression included a modified version of the National Child Traumatic Stress Network's Hurricane Assessment Tool (Peterson, 2017) that had been used in New Orleans after Hurricane Katrina; the Child PTSD Symptom Scale (CPSS) (Foa et al., 2001); the Strengths and Difficulties Questionnaire (SDQ) (Goodman et al., 2000), the Children's Depression Inventory 2 (CDI-2) (Kovacs, 2019) or Beck's Depression Inventory 2 (BDI-II) for adolescents (Beck et al., 1996), and the CRAFFT (Knight, 2016) substance abuse screening tool for adolescents (D'Amico et al., 2017). A comparison of pre- and post-intervention PTSD and depression assessment scores revealed that PTSD had been reduced more than depression as a result of the intervention. Due to the intervention's success at reducing the mental health impacts of Superstorm Sandy and increasing individual and school resilience, the COAST model was selected for inclusion in the socio-emotional literacy curriculum for the Long Beach school district.

Rockaways, New York, after Hurricane Sandy.
Photo by Mary McKenna.

Resilience and Coping for the Healthcare Community intervention

The Resilience and Coping for the Healthcare Community (RCHC) mental health intervention (Powell and Yuma-Guerrero, 2016) focused on building resilience among its New York and New Jersey participants. Participants included health care and social service providers that operated in the dual roles of survivor and disaster response provider during and after Hurricane Sandy. The RCHC intervention increased local partnerships with three community health centers, two social service agencies, and one disaster response organization through staff cohesion and team building.

Participants completed surveys before and after the psychoeducational intervention, with one additional follow-up three weeks later to report on their experiences responding to or surviving Superstorm Sandy. Semi-structured interviews were conducted with 10 participants from five of the six intervention sites. Tools used to measure mental health resilience included the Professional Quality of Life Measure (ProQOL 5) (Stamm, 2009) for professionals helping others through trauma, the Perceived Stress Scale (Cohen et al., 1994), a self-reporting stress checklist (Cox & Mackay, 1985), and the Coping Self-Efficacy Scale (Chesney et al., 2005). Metrics included self-reported levels of stress, fatigue, burnout, coping strategies, satisfaction, and knowledge.

Ready CDC community resilience intervention

The Ready CDC intervention increased community resilience among 208 CDC staff participants in Morgantown, WV, Atlanta, GA, and Fort Collins, CO, through emergency preparedness education and activities (Thomas et al., 2018). Metrics included a pre- and post-assessment of knowledge, beliefs, self-efficacy, and stage of household preparedness using the Transtheoretical Model (TTM) of behavior change (Prochaska and DiClemente, 1983; Prochaska et al., 1992), (Figure 5). The study used a TTM-based survey instrument to measure changes in emergency preparedness behaviors and attitudes towards community resilience. Behavior metrics included participants signing up for emergency notifications and encouraging others to prepare for emergencies (Thomas et al., 2018).

> ***"There are not enough resources to deal with a disaster. We have multiple phases of rescue and emergency response. We need a regional response team for those whose resources run out with multiple calls."***
>
> ***— [Fire Chief at Monadnock Region BRACE Stakeholder Meeting, 2018]***

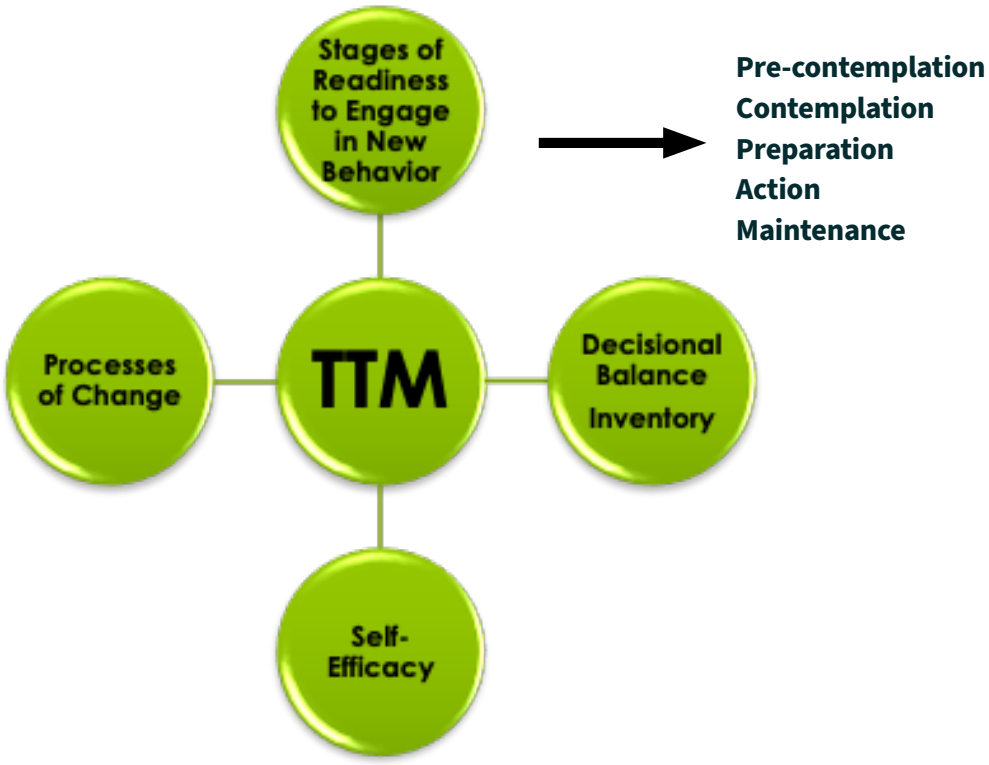


Figure 5. Core constructs of the TTM (Abrash Walton, 2018).

The TTM is an evidence-based psychological approach to understanding and facilitating behavior change (Abrash Walton, 2018). The TTM has four major constructs: (a) stages of readiness to engage in a new behavior; (b) decisional balance inventory; (c) self-efficacy; and (d) processes of change (Figure 5). The stages of readiness to engage in a new behavior construct is based on the theory that there are five recognizable stages associated with any given behavior change.

These stages are:

1. Pre-contemplation—not ready to engage in the new behavior (e.g., not aware, in denial)
2. Contemplation—considering engaging in the new behavior
3. Preparation—actively preparing to engage in the new behavior
4. Action—engaging in the new behavior
5. Maintenance—continuing the new behavior for at least six months

Progress through these stages is not necessarily linear or steady. For example, a person might spiral through contemplation, preparation, and action more than once. The decisional balance construct is based on the understanding that decision-making requires consideration of potential positive and negative consequences. The self-efficacy construct concerns an individual's confidence in engaging in the new behavior. Self-efficacy can influence motivation and persistence in engaging in the behavior change. The fourth TTM construct is the ten processes that can support behavior change. Specific processes tend to support effective movement through the stages when provided at a particular stage.

COPEWELL Rubric social capital and community engagement assessment tool

The pilot of the COPEWELL Rubric's social capital and cohesion tool increased local partnerships, enhanced social cohesion, and increased risk communication and knowledge using a bottom-up approach to community self-assessment (Schoch-Spana et al., 2019). During Phase 1, the rubric was developed by public health practitioners and social science researchers with expertise in community resilience, public health policy and emergency preparedness. Prior to launching a pilot trial, the rubric was reviewed by 13 stakeholders from local, state, and federal sectors and then used in a mock exercise with 30 public health preparedness professionals at the 2018 Annual Public Health Preparedness Summit in Atlanta, GA (Schoch-Spana et al., 2019). The rubric was then piloted with stakeholders representing municipal, county, and utility agencies. In its final phase of the pilot intervention, the social capital and cohesion self-assessment tool was implemented in Coatesville, PA, with 18 community members representing community-based organizations and local citizens.

Metrics included social support within the community, connections to the neighborhood and larger municipality, active community organizations, and opportunities for individuals and community organizations to engage in emergency preparedness planning, response, or recovery. Community engagement and buy-in were noted at the end of the tool's evaluation when the county partners committed to implementing additional domains from the rubric. Additional domains of the COPEWELL Rubric are now available for: population vulnerability, inequality and deprivation; community functioning; emergency management; and prevention/mitigation.

The COPEWELL self-assessment rubrics and implementation guides are available online at:
https://www.copewellmodel.org/self-assessment-tools.html

Garden State community resilience tool

The Garden State community resilience tool focused on community strengths and weaknesses in relation to disaster preparedness and resilience. The Garden State assessment tool was piloted in Secaucus, a densely-populated New Jersey community affected by Superstorm Sandy, to identify the needs of vulnerable populations based on emergency preparedness procedures (Bowman and Newman, 2017). The assessment was implemented in two phases during the course of one year. In the first phase, the community's municipal and emergency operations were reviewed, including existing plans and procedures. City officials contributed their expertise via interviews. The second phase focused on the identification of community threats, hazards, and risks using historical information and mapping of floodplains. An analysis of the populations and the community's assets was also conducted.

Metrics included county and state demographics for comparison, including at-risk populations and population density; and county emergency planning policies, including pre-event planning, municipal operations, recovery, and mitigation. The authors did not indicate if the implementation of the tool increased partnerships for emergency preparedness initiatives. The model has since been expanded to assist other New Jersey communities.

Evidence-Based Metrics for the Five Selected Articles

The formative and summative metrics used to measure community resilience varied with each intervention or tool. Preparedness and recovery interventions focused on formative metrics such as knowledge, coping skills, and mental health, while the resilience tools measured social connectedness and partnerships, pre-event planning, and community functioning. The summative metrics indicated an increase in community resilience and decreases in mental health impacts associated with Superstorm Sandy. All three mental health and community resilience interventions were successful in increasing knowledge related to emergency preparedness and risk reduction.

Each project met at least four of the CDC's seven national standards for community resilience (Figure 6); the COAST intervention was the only project that met all seven.

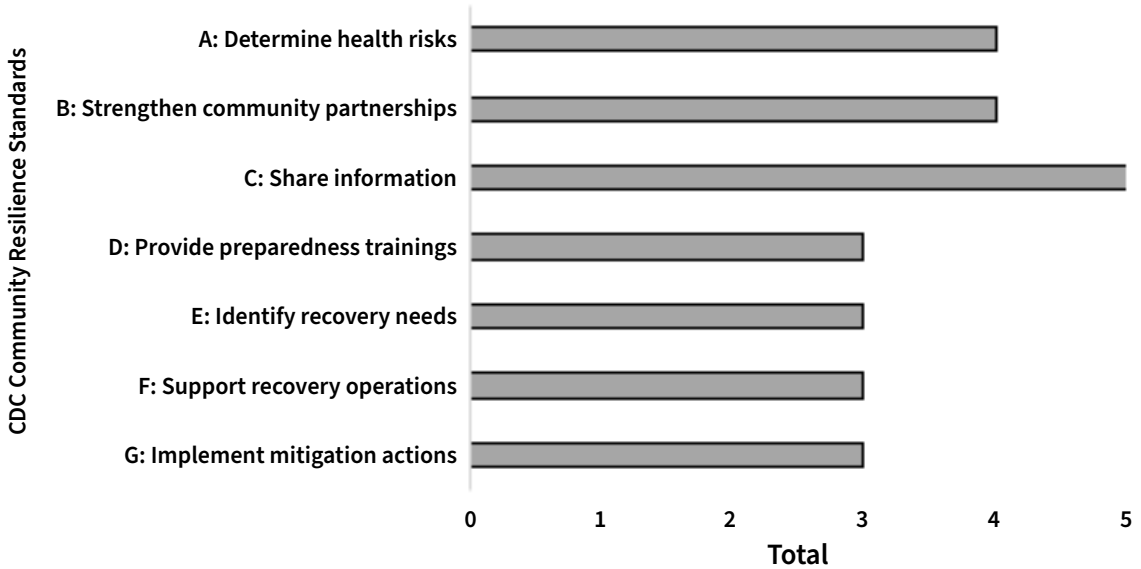


Figure 6. **Number of projects meeting the CDC national standards for community resilience.**

A list of the metrics discussed in all 24 articles is available from the authors as a supplement to this report. A list of toolkits is available in Appendix B.

Discussion

In our review of the initial 205 articles on community resilience interventions and metrics for the Northeast and the Mid-Atlantic states, we found five articles (2.4%) that discussed interventions which had been implemented and evaluated. The results of this literature review support previous research which found that, despite a plethora of articles on theoretical frameworks and community resilience tools, few exist that demonstrate an evaluation of the tools or interventions to measure and build community resilience (Chuang et al., 2018; Eisenman et al., 2014; Ostadtaghizadeh, 2015; Schoch-Spana et al, 2019). This finding highlights the need for an evaluation of frameworks that study the resilience and post-disaster recovery of communities affected by climate-related hazards such as hurricanes and flooding (Koliou et al., 2018).

Evidence-Based Metrics for Community Resilience: Similarities and Differences

An intervention must be evaluated to know if it succeeded in enhancing community resilience (Chandra et al., 2011). Here, we compare the metrics used to measure community resilience in the five selected interventions and tools: 1) COAST Project mental health intervention; 2) RCHC mental health intervention; 3) Ready CDC community resilience intervention; 4) Garden State community resilience tool; and 5) COPEWELL Rubric community engagement assessment tool.

The five selected articles (Table 4) used relatively simple, often low-cost data collection methods, including participant knowledge, pre and post surveys, semi-structured interviews, and focus groups. The metrics reflected aspects of a resilience domain that could be easily measured, such as the stage of household preparedness, or the number of community organizations engaged in emergency preparedness initiatives.

In contrast, some interventions, tools, and research (Appendix) used more complicated, time-consuming, or costly methods to obtain data, making their use less accessible to local health practitioners and emergency planners. For example, data imported into the Resilience to Emergencies and Disasters Index (REDI) tool to assess neighborhood resilience after Superstorm Sandy (Kontokosta and Malik, 2018) included access to the 311 call system for New York City, information on the public transportation systems, hurricane evacuation centers, and access to the census of street trees in the city. During a pilot of the COPEWELL model for hurricane resilience across the United States (Links et al., 2018), county-level data were obtained on transportation infrastructure, physical distance to coastlines, socio-economic information, and social organizations. The study on coastal storm vulnerability for U.S. counties along the Atlantic coast (Sajjad et al., 2020) required population distribution data, natural habitat information, historical sea level trends, and coastal topology and elevation data to develop a Coastal Risk Index. Despite most of the data's availability online, acquiring and processing such data may be time-prohibitive for local planners and public health agencies. In addition, the development of the Recovery Indicators Tool (Dwyer and Horney, 2014) highlighted the reality that not all data may be available for all metrics, increasing the uncertainty of a tool's effectiveness in measuring or enhancing community resilience.

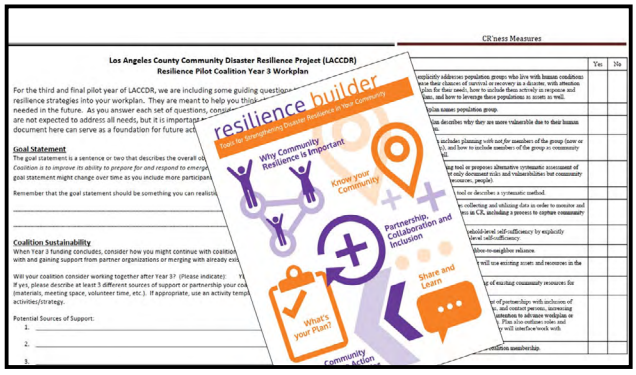
Data that are not relevant, including climate change projections, or accessible to local planners in a way that reflects their ability to collect, interpret, or use them, are data that may be misused or not used at all (Abrash Walton et al., 2016). Relying upon participant-based and publicly available U.S. Census data may be the most affordable option for smaller communities with limited financial and personnel resources.

While searching the literature for articles on community resilience interventions, we surfaced two in-depth case studies of public health community resilience interventions: one well-developed community resilience framework from Los Angeles County; the other, from New Hampshire. We describe these case studies here and note that each offers specific intervention methods that could be applied to community resilience interventions in the Northeast. The first case study also provides metrics and an evaluation framework.

Case Study: Community resilience and the Los Angeles County community disaster resilience project

The Los Angeles County Community Disaster Resilience Project (LACCDR) was a two-year project in which community-based strategies were to increase the ability of 16 urban neighborhoods in Los Angeles County to prepare for, respond to, and recover from a public health threat or natural disaster (Eisenman et al., 2014). The project focused on four community resilience indicators: education; self-sufficiency; community engagement, and organizational partnerships.

Neighborhood communities were selected based on demographic and hazard risk characteristics that included population size (<11,000 to <150,000), diversity of race/ethnicity, median household income ($26,000-$97,000), and the percent of renters in the population (>10 to 96%) (Eisenman et al., 2014). Each community was represented by a coalition of at least two community-based organizations, such as fire/police, school, community hospital, or business community, and a community structure sufficient to implement the LACCDR project, such as emergency managers or town committees.



Resources developed by the LACCDR Project included a resilience builder toolkit, and community resilience workplan and worksheet.
From: http://www.laresilience.org/resources/

The communities were divided into two groups. Community coalitions in the experimental group received community resilience training using a tool kit that included: a) psychological first aid; b) community mapping of resources and populations in need; c) identifying community leaders; and d) training field workers, such as nurses and school staff; and developed a written plan to improve community resilience in their neighborhood (Eisenman et al., 2014). Community coalitions in the control group received emergency preparedness training on emergency kits and communication plans and wrote preparedness plans for personal and household self-sufficiency. Wellness, education, engagement, and partnership were measured using pre and post surveys.

Project outcomes were evaluated by a population-based survey, an organizational network survey, and tabletop exercises with the community coalitions engaged in the project. The population-based survey, that measured the outcomes of education and resilience activities, was sent in English, Spanish, and Korean to 4400 households (Eisenman et al., 2014). Neighborhood coalitions were asked questions including:

- Who are your most vulnerable community members?
- How are you using the information you collected to get your neighbors and your community prepared, ready to respond, and able to recover from a disaster or emergency?
- How are you coordinating the work of first responders and community members to avoid

overlap and keep information flowing and lines of communication open?

- How are organizations and agencies in your community involved in planning for the recovery process? (Eisenman et al., 2014, p. 8484).

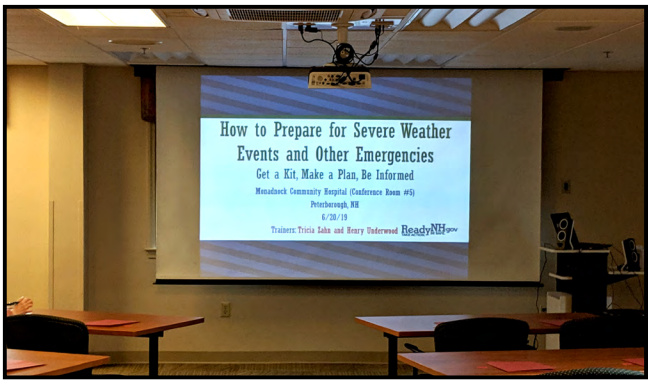
Organizational partnerships that networked to increase emergency preparedness or community resilience were measured using the PARTNER tool (Visible Network Labs, 2010), an online social network analysis program (Williams et al., 2018). The tabletop exercise simulated a heatwave and drought scenario and was designed to identify gaps in partnerships or resources that would hinder mitigation or recovery efforts, and that were tied to the four community resilience indicators (Chandra et al., 2015a). Questions included:

- What plans should be put in place in your community to make sure you are ready for this heat increase? What is each organization going to do? [measures organizational partnerships]
- Suppose the senior population is having more problems because air quality has gotten worse? What are the plans to make sure there is adequate outreach? [measures community engagement]
- The community seems to be getting frustrated with government response. How would your coalition convey information and reduce frustration? [measures education]
- Can the community handle the stresses? What tells you the community can overcome these challenges? [measures self-sufficiency] (Chandra et al., 2015a, p. 485).

Collectively, more than 100 community-based organizations, social services, educational institutions, physical and mental health agencies, emergency services, businesses, municipal and state government agencies, town committees, and task forces participated in the project's neighborhood coalitions. Both the community resilience group and the emergency preparedness group demonstrated improvements in three community resilience indicators: education; self-sufficiency; and community engagement (Cha et al., 2016). The fourth indicator, organizational partnerships and collaboration, was difficult for the control group coalitions engaged in emergency preparedness; they experienced challenges with public apathy that affected their ability to engage agencies representing at-risk populations and to develop a coordinated response to disasters (Chandra et al., 2015a).

Case Study: Greater Monadnock Public Health Network BRACE initiative

The CDC developed the Climate-Ready States and Cities Initiative (CRSCI) to help public health grantees from 16 states and two cities (New York City and San Francisco) to identify both the health impacts associated with climate change, and the at-risk populations within their jurisdictions. The initiative's goal was to create and implement climate and health adaptation plans using the Building Resilience Against Climate Effects (BRACE) framework (CDC, 2020b; Marinucci et al., 2014). The BRACE framework combines climate science with strategies for building community resilience. The goal is to reduce health risks associated with: a) increased exposures to intense storm events, floods, droughts, heat waves, and diseases; and b) changes to air, water, and food (Ebi et al., 2018).



The GMPHN led a series of workshops on emergency preparedness for area seniors during a pilot intervention in southwest NH in 2019.
Photo by Henry Underwood, used by permission.

The BRACE framework consists of five steps:

1) forecast climate impacts and assess vulnerabilities;
2) project the disease burden;
3) assess public health interventions;
4) develop and implement a Climate and Health Adaptation Plan (CHAP);
5) evaluate impacts and improve the quality of activities (Centers for Disease Control and Prevention, 2019; Manangan et al., 2015).

The New Hampshire Greater Monadnock Public Health Network (GMPHN) used the BRACE framework to guide the development and pilot of a climate and health intervention. GMPHN used the NH SVI to identify communities and populations at highest risk for flood-related injuries in the southwest region of New Hampshire (Greater Monadnock Public Health Network, 2016). During the creation of the Climate and Health Adaptation Plan (CHAP), the GMPHN selected community resilience indicators with which to measure community health resilience and adaptation. Indicators included hazards, environment, transportation, housing, economy, health, and demographics. Community partnerships or engagement in social or civic organizations were not listed as indicators of community resilience. Metrics included:

- Percentage of land in a 100-year floodplain
- Percentage of land with low or poor air quality (elevated particulate matter PM2.5)
- Access to public transportation
- Access to healthy food
- Access to a pharmacy
- Percentage of households with resident living alone
- Percentage of the population over 16 that is employed
- Proximity and access to hospitals and clinics
- Age (under 5, under 18, over 65, over 85)
- Low income (at or below 200% of the poverty rate) (Greater Monadnock Public Health Network, 2016, p. 49).

In Phase 1, organizations participating in the CHAP met in 2016 and 2017 to develop a pilot intervention aimed at individual emergency preparedness for seniors over age 65 (Greater Monadnock Public Health Network, 2018). The workshop-style intervention consisted of two similar workshops, one at a senior center, and one at a senior assisted-living facility. The training format was comprised of emergency preparedness instruction and printed, educational resources. Each intervention began and ended with a participant survey to measure the effectiveness of the presentation. One performance measure, the number of new subscribes to NH Alerts for emergency or severe weather notifications, increased during the month in which the two pilot interventions were implemented. Prior to the workshop, 26% of the 19 participants rated their emergency preparedness 4 or 5 out of 5 on a scale; at the end of the intervention, 40% of the participants rated their preparedness at 4 or 5 out of 5 (Greater Monadnock Public Health Network, 2018).

Phase 2 of the GMPHN project built upon the initial pilot intervention during 2018 with a series of stakeholder meetings, including sessions with seniors over age 65. The purpose of the meetings was to inform a plan of action and develop a pilot intervention. The

focus of the intervention was on increasing emergency preparedness and resilience to extreme precipitation events within the senior population through education, and the development of emergency plans, contact lists, and emergency kits. In 2019, the pilot intervention was implemented at four different locations throughout the region where seniors congregated: a senior center; a friendly meals site; a senior housing agency; and a support agency for seniors living at home. During the four workshops, a lecture-style format reached 60 participants who learned about emergency preparedness in relation to climate and extreme precipitation events; created written emergency plans with contact lists; subscribed to the NH Alerts early warning systems on their cell phones; and received a pre-packaged stay-at-home emergency kit (Greater Monadnock Public Health Network, 2019). Intervention outcomes were measured using a survey at the start and end of the workshop and six weeks later by U.S. mail. Questions were based upon perceived emergency preparedness [self-efficacy] and the stages of preparedness using the Transtheoretical Model (TTM) of behavior change (Prochaska & DiClemente, 1983). At the start of the workshop, 13% of the 55 participants who completed the pre-intervention survey indicated that they were preparing their emergency plan; by the end of the workshop, 42% of those 55 participants were creating their plan. Six weeks later, 44% of the responding participants (n = 18) indicated that they were preparing their plan, while 17% of the 18 participants who responded were at the maintenance stage of having a plan and keeping it current (Greater Monadnock Public Health Network, 2019).

In its next phase, the GMPHN BRACE project may update the emergency preparedness training workshops to be administered via a remote learning platform due to the COVID-19 pandemic, and as a way to reach out to rural community members. This phase will also include a community resilience strategy using a multi-media information campaign to raise population-level awareness of disaster risks and community resources.

"Teach people how to not be victims so we don't have to rescue them. Sometimes we have to leave these people to go to other calls and they really shouldn't have been left alone."
— [First Responder, Monadnock BRACE Stakeholders Meeting, 2018]

Discussion: People at Risk During Extreme Precipitation Events

- **NOTIFICATION:** How are you notified about extreme precipitation events such as flooding?
- **HEALTH ISSUES:** What health issues have you experienced or witnessed, before, during, or after an extreme precipitation event?
- **ASSISTANCE:** What kind of help was needed, by you or someone you assisted, before, during, or after extreme precipitation events?
- **EMERGENCY PREPAREDNESS:** What kinds of emergency preparedness measures were in place before, during, or after an extreme precipitation event? How could they have been improved?
- **FUTURE SERVICES:** What programs or tools would you like to have offered to reduce health issues caused by extreme precipitation events?

Sample questions used during the 2018 GMPHN stakeholder sessions to inform the plan of action and pilot intervention.

Strengths and Weaknesses of Community Resilience Interventions and Tools

Study authors and participants critiqued interventions and tools in this review. We discuss those critiques here with the intention of informing development of future interventions. Participants who contributed to the development of the Resilience Indicators Tool, which was created to measure disaster recovery, suggested that the tool was flexible enough to be used for a pre-disaster assessment, as well as an indicator of post-disaster recovery (Dwyer & Horney, 2014). We believe the Ready CDC intervention may also be adapted for pre-and-post-disaster assessment, as well as individual and community resilience. Ready CDC combined emergency preparedness education with behavior change theory in a model that could easily be adapted for use by adults in a school, workplace, or community setting.

Authors offered suggestions on what to do with the knowledge gained from the implementation or evaluation of the intervention or tool. For example, community resilience assessment tools would be more beneficial to planners and public health officials if they went beyond a current assessment of the community; additional information could include recommendations for actions that are customized to a community's needs (Johansen et al., 2017). This feedback was similar to the request made by participants of the COPEWELL Rubric who wanted a tool that could be adapted for municipalities with different resource levels (Schoch-Spana et al., 2019).

Intervention and Tool Development and Deployment Costs and Structures.

We reached out to the authors of seven articles in this review who used surveys, focus groups, and participant interviews for data collection and asked about the costs for the interventions, the hours and staffing structure involved, and any funding they received.

One author reported that the costs for piloting a disaster recovery assessment tool were $23,000 for supervised graduate student stipends over nine months totaling approximately 280 hours. Research included a literature review, two case studies, two focus groups, and 21 interviews with experts from academia, and public and private practice. Multiple research papers resulted from the project.

The development of a disaster preparedness assessment tool for local health departments incurred nearly $250,000 for each of the first two years for research and development and $50,000 during the third year to develop the toolkit. The piloting of the tool took four months and included a survey of 274 disaster preparedness coordinators from local health departments across the country.

A post-disaster mental health intervention that involved two school districts in 10 locations took two years to complete. Activities addressed trauma and coping skills and included art therapy, workshops, service learning, and therapy. Full-time staff included a licensed social worker as program manager and a psychology fellow. Part-time staff included two social workers, a psychologist, a psychiatrist, a nurse practitioner, and two psychology students. The overall program budget was $1.2 million.

Financial support was received from Americares, the CDC, and New York social services school grants.

Community Resilience Interventions and Tools for Severe Weather Events

We believe that both of the hurricane-related interventions that focused on mental health resilience could be applied to other severe weather events, such as flooding or extreme winter storms. The COAST model in particular, because of its institution-based approach, could be adapted for use in nursing homes, prisons, or the workplace. The interventions were tailored to the target populations and could be adapted for smaller communities, communities with less resources, and communities from different geographic regions.

Other severe weather events represented in this review included coastal and winter storms, drought, heat waves, and flooding. Although the tools had not been implemented and evaluated to demonstrate their ability to measure or enhance community resilience, many of them could be piloted for localized, severe weather events. For instance, the Fault Tree model (Chodur et al, 2019), which incorporated road systems data, may identify transportation system vulnerabilities for local planners working to improve recovery and resilience during floods, severe wind events, ice storms, or fires that disrupt accessibility to local road systems.
While built on food systems resilience, the model could be applied to emergency supplies or other health-related resource needs and incorporated into a resilience-building intervention.

Pre-planning is paramount to community recovery efforts and resilience during and after an event. A community resilience study in New York after Superstorm Sandy found that recovery partnerships formed before an event were more sustainable than partnerships formed during or after an event occurred (Acosta et al., 2018). Zukowski (2014) in an assessment of community resilience for all U.S. counties, found that response and recovery were improved in communities that incorporated pre-planning, protocols, exercises, and community engagement in the form of education, exercises, and community partnerships. The Assessment for Disaster Engagement with Partners Tool (ADEPT) model could be used as a baseline tool for local planners wanting to assess community partnerships before developing a disaster preparedness and recovery network; higher scores on the assessment indicate more active relationships with community and faith-based organizations (Glik et al. 2014).

NH residents used a foot bridge for several weeks to access their home after an extreme precipitation event destroyed the road.
Photo by Janine Marr.

Gaps in the Literature

Our review found several gaps in the literature. First and foremost is the lack of interventions, tools, and metrics that have been implemented or evaluated in the New England region. This review located interventions that reflected impacts of hurricanes and floods upon relatively large geographic areas. There is a need for research and interventions to build community resilience in smaller communities with localized disasters, especially for communities that do not qualify for FEMA funding, regardless of disaster impact, due to lower recovery costs or geographical area damaged.

Our search returned no results of interventions designed to address the health impacts associated with climate-related hazards and that are increasing in New England: extreme flooding; extreme heat; mental health impacts; and vector-borne diseases such as Lyme disease (New Hampshire Department of Health and Human Services, 2016; USGCRP, 2018). We found no interventions that addressed the mental health challenges of multiple events, such as a hurricane followed by flooding followed by a heat wave, or a heavy snow or ice event followed by flooding or a power outage.

For example, many rural communities in Vermont were devastated by the destruction of the transportation and communication systems resulting from the flooding caused by Tropical Storm Irene in 2011 (Pierre-Louis, 2016); they did not have the resources to adapt and implement a disaster recovery assessment tool for their recovery needs. We view these gaps in the literature as opportunities for targeted research to advance the field of community resilience.

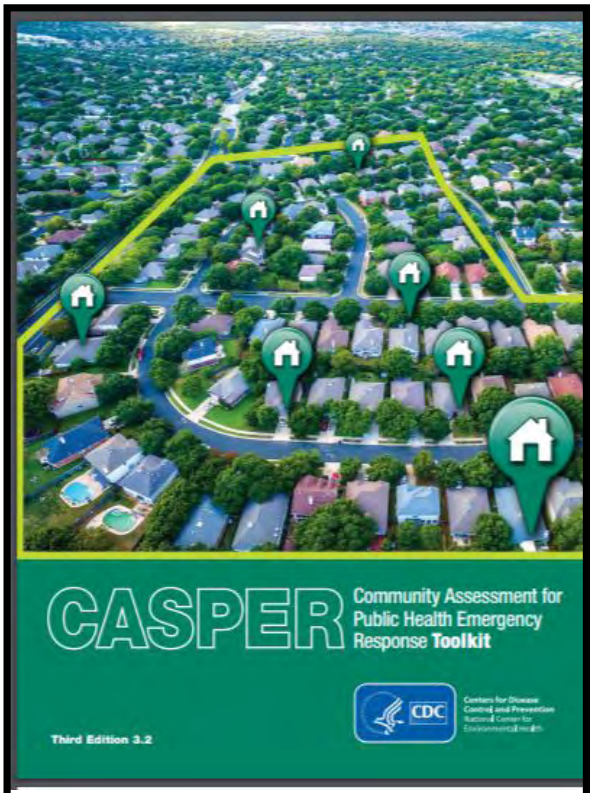
We attribute the lack of evidence-based literature in part to the way in which databases and search engines are designed. Our search returned no published studies on community resilience in New England; however, we know that studies do exist. We believe the issue is that some tools and metrics are published in journals that appear in specific databases so our searches are not capturing all of the relevant articles. For example, despite most of our initial articles appearing in the Web of Science, four of the five articles that met our criteria were found using PubMed.

Wilmington, VT after Tropical Storm Irene in 2011.
Photo by Eric Craven 8/28/11. Used with permission.

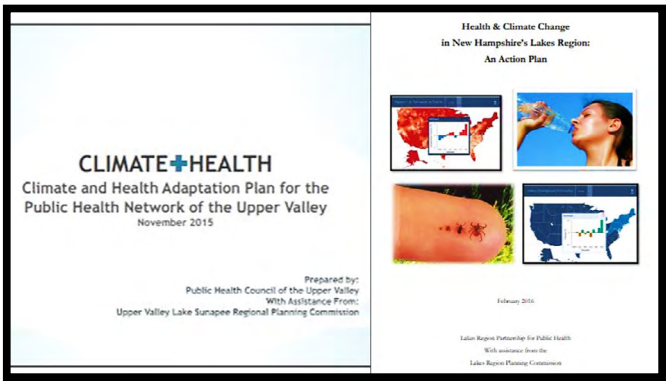
Limitations

There were limitations for this review that may affect the applicability of its findings. Our review explored literature from the Northeast and Mid-Atlantic regions, and in particular, studies with a focus on community resilience. As a result, studies that reported on interventions or tools focused on extreme weather in other regions of the United States were not included. Studies that did not view the research from a resilience framework may not have been selected for this review. For example, we were unable to compare the interventions in this review with interventions from 35 states outside the Northeast that used the CDC's Community Assessment for Public Health Emergency Response (CASPER) tool as a component of the intervention (Centers for Disease Control and Prevention, 2020a). CASPER generates an interview-based, household-level, public health needs assessment for disaster awareness, preparedness, response, and recovery (Centers for Disease Control and Prevention (CDC), 2019). CASPER has been used for community health assessment, emergency preparedness, and tick and mosquito bite prevention in New England, and to assess Superstorm Sandy response needs in New York.

Another potential limitation of this study was that we included only peer-reviewed articles, eliminating gray literature, such as white papers, dissertations, and publicly available articles. Climate and health adaptation plans and interventions have been implemented in New England using the BRACE framework to address extreme precipitation, heat stress, tickborne illness, and other climate-related hazards (New Hampshire Department of Health and Human Services, 2016b). However, these works do not appear in the peer-reviewed literature and therefore, were not added to the small list of evidence-based interventions on community resilience.



The CASPER Toolkit, version 3.2, is available online at: https://www.cdc.gov/nceh/casper/docs/CASPER-toolkit-3_508.pdf



Two CHAPs that informed climate-related interventions in New Hampshire are available online at: https://www.dhhs.nh.gov/dphs/climate/publications.htm

Recommendations

Local planners and public health professionals who wish to measure community resilience need readily available resources that are cost effective, time efficient, and easy to access, whether they want to implement an intervention, or just establish a baseline assessment for community resilience planning. We propose that much of the data needed for measuring resilience can be generated through the use of semi-structured interviews, surveys, and focus groups. Additional demographic and socio-economic data can be gathered from publicly available sources, such as the U.S. Census website. Online mapping tools, including the National Environmental Public Health Tracking Program (Centers for Disease Control and Prevention, 2020b), weather stations, and local emergency preparedness, mitigation, and recovery plans can generate low-cost data needed for other metrics. We suggest that community partnerships are a critically important resource for additional data as community-based organizations and other local entities may have access to resources and personnel unavailable to smaller local governments.

We recommend that interventions to build community resilience attempt to: 1) use pre- and post-intervention surveys to document progress and participant input; 2) engage the community in the entire process; and 3) publish the results to inform other local planners and public health officials while advancing the field of community resilience.

We believe an intervention and set of metrics based on the COAST project and the COPEWELL Rubric could be successfully adapted and applied to a smaller New England community to build community resilience to extreme weather events that may include hurricanes, floods, or heatwaves. In our work with the BRACE framework in New Hampshire, which has focused on emergency preparedness and severe weather, we encountered stakeholders who had experienced deadly floods and other traumatic events. Incorporating mental health wellness into emergency preparedness initiatives would engage additional community members and organizations, increase partnerships, and build resilience at both the individual and community levels. Similar to the BRACE framework, the COPEWELL Rubric engages the community throughout the process, from deciding upon a common language for community resilience, to developing goals and an action plan to strengthen resilience, and evaluating progress. One benefit of the COPEWELL Rubric for communities with few resources is that each of the modules, including healthcare and public health, social capital and cohesion, and natural systems, can be addressed separately as time, priorities, or resources permit, rather than assessing several resilience indicators at the same time.

Replicating the use of these tools for assessment and enhancement of community resilience would: 1) advance our knowledge of the intervention or tool's effectiveness over time; 2) indicate the stage of recovery for the community; and 3) determine the community's adaptive capacity and resilience.

We recommend that local planners and public health practitioners review the literature cited in this paper for suggestions on enhancing community resilience in their own jurisdictions. We encourage local health officials to implement community resilience interventions using evidence-based models, and frameworks, such as BRACE, which has low exposure in the peer-reviewed literature. We encourage those developing tools and frameworks to engage the community in piloting and improving tools for low-cost implementation using readily accessible data. We encourage community engagement and public participation in initiatives that increase social cohesion and ownership of both the process and outcome known as community resilience.

Conclusion

This review advanced understanding of the depth and breadth of peer-reviewed literature from the Northeast and Mid-Atlantic regions that is currently available to serve as models for building and measuring community resilience. Our review demonstrated that the public health and resilience community has conducted assessments to determine health risks within a community that align with some of the CDC national standards. However, of the 24 studies in our review, there were few that demonstrated evidence-based interventions or tools designed to enhance community resilience and which had been implemented and evaluated. We found five evidence-based projects to guide local planners and public health officials in designing and implementing their own resilience interventions.

The models that best approached strengthening and measurement of public health dimensions of community resilience were the COAST project and the COPEWELL Rubric. We suggest that these models could be adapted for use by public health officials in other states or regions, in other settings, and with other populations or extreme weather events to achieve the U.S. National Preparedness Goal. The models used easily accessible data sources, including participant-based data. They demonstrated the use of metrics to measure the extent to which community resilience was enhanced through these interventions. The Ready CDC intervention, which incorporated the TTM behavior assessment method, offers an easy-to-implement, evidence-based approach. Although we found no peer-reviewed literature on evidence-based interventions using the BRACE framework in the Northeast, we believe that this model can also be easily implemented at the local level. Gaps that we identified in the literature offer rich applied research opportunities moving forward. We encourage local planners and public health officials to draw on the insights gained by this review to enhance community resilience in their own jurisdictions through adaptation and implementation of the interventions and metrics discussed here.

> ***"The biggest need is knowing who's vulnerable and getting information to them, rather than having the tools available."***
> ***— [Social Service Organization Staff Member at Monadnock Region BRACE Stakeholder Meeting, 2018]***

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Appendix A: Community Resilience Interventions and Metrics with Climate Focus and Health Impact

Climate and Health Focus	Target Population and Location	Study Type	Formative Metrics (Unit Measured)	Summative Metrics (Health-Related Outcomes)	Method/Data Sources	Data Available Locally?	2011 CDC National Standards[a]	Source
Hurricane recovery (Superstorm Sandy) and mental health resilience	Community mental health workers in NY & NJ	Mental health intervention	Self-efficacy, stress response, coping strategies, demographics	RCHC intervention increased perceived knowledge and decreased stress scores.	Participant surveys and interviews before, during, and after education intervention	✓	b, c, d, f	Powell & Yuma-Guerrero (2016)
Hurricane and flood recovery (Superstorm Sandy), community mental health	Residents of Long Island, Queens & Rockaways, NY	Health study	Hurricane exposure (including flood severity), PTSD	More participants from the Rockaways reported PTSD symptoms than from Queens and lower Manhattan.	LIGHT Study, Project Restoration, World Trade Center Health Registry	✓	a, c, e	Schwartz et al. (2019)
Hurricane recovery (Superstorm Sandy) and mental health	Residents of Oakwood, NY	Health study	Effects of buyout program on peripheral community	Peripheral community experienced loss of safety, and trust in government, affecting recovery process.	Qualitative interviews with residents near buyout zone; field notes from interviewers	✓	a, c, e	Binder et al. (2020)
Hurricane recovery (Superstorm Sandy) and mental health	Residents of New York City	Health study	PTSD, depression, location, demographics	Mapped results showed clusters of PTSD and depression more prevalent in areas exposed to the ocean.	Telephone survey, Posttraumatic Stress Checklist, Patient Health Questionnaire; NYC Department of City Planning	✓	a, c, e	Gruebner et al. (2015)
Hurricane recovery (Superstorm Sandy) and mental health	Residents along the eastern shore of Staten Island, NY	Community resilience study	Perceived recovery, neighborhood satisfaction	Residents satisfied with neighborhoods and/or had a college education perceived a higher recovery rate.	Mail survey to residents; US census	✓	c	Frey, N. (2017)
Hurricane recovery (Superstorm Sandy) and community resilience	Students, parents, teachers in Far Rockaway and Long Beach, NY	Mental health intervention	Coping skills, behavioral risk and stress reduction, PTSD, depression	Youth PTSD and depression reduced; model adopted for Long Beach's curriculum; students created YouTube PSA.	Pre and post survey of students, parents, educators, and school-based providers participating in COAST Project	✓	All of the above	D'Amico et al. (2017)
Hurricane recovery (Superstorm Sandy) and community resilience	Community in Hudson County, NJ	Community resilience tool	Pre-event planning, municipal operations, demographics	Piloted Garden State model; community in need of Continuity of Operations Plan for flooding, storm surge, and sea level rise impacts.	Emergency plans; geospatial mapping of flooding, sea level rise, and storm surge; risk assessment index; in-person discussions	✓	a, b, c, e, f, g	Bowman & Newman (2017)
Hurricane (Superstorm Sandy) and urban neighborhood resilience	Residents of New York City	Community resilience tool	Distance to emergency services and transportation, % of area flooded	REDI found that neighborhood resilience capacity decreased as distance from public transportation and city infrastructure increased.	NYC 311 system; US census; NYCDCP; MTA; FEMA Hurricane Sandy Impact Analysis; NYC Emergency Management Hurricane Evacuation Centers; NYC Directory of Parks Properties; NYC Street Tree Census	May be time-consuming; data available online	c, e	Kontokosta & Malik (2018)
Hurricane (Superstorm Sandy) and community partnership network resilience	Community-based organizations in New York City	Community resilience study	Structure and durability of partnerships, storm exposure and effects	Recovery partnerships formed before disaster were more sustainable than partnerships formed after and in relation to disaster.	Online survey to partnership networks of community-based organizations and NY Department of Health and Mental Hygiene	✓	a, c, e	Acosta et al. (2018)

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Climate and Health Focus	Target Population and Location	Study Type	Formative Metrics (Unit Measured)	Summative Metrics (Health-Related Outcomes)	Method/Data Sources	Data Available Locally?	2011 CDC National Standards[a]	Source
Hurricane recovery (Superstorm Sandy)	Residents of Oakwood Beach and Rockaway Park, New York City	Community resilience study	Disaster management, exposure to hurricane, demographics	Loss of neighborhood and sense of place affected a community's decision to relocate or rebuild.	Survey based on CART resilience domains; interviews with residents	✓	c, e	Binder, Baker, & Barile (2015)
Community recovery and resilience (hurricane example)	Counties in the United States	Community resilience tool	Population demographics, infrastructure, and community resources	Piloted the COPEWELL model; produced a county-level map of community functioning and resilience	County level data	May be time-consuming	a, b, c, e	Links et al. (2018)
Hurricane (Superstorm Sandy) and coastal port resilience	Stakeholders of the Red Hook Container Terminal, Brooklyn, NY	Community resilience study	Damages interrupting operations and impairing recovery	Disruption of food, blood, medical and emergency supplies; emotional toll from damage and power outages; recovery impaired where no pre-event coordination.	Interviews with stakeholders (Port Authority of NY & NJ, Coast Guard, Portside New York); review of news and technical damage reports	✓	c, e	Ryan-Henry & Becker (2020)
Diverse threats (winter storm, drought) and food system resilience	Residents of city of Baltimore, MD, and state of California	Community resilience tool	Barriers to transportation, supply, distribution; production failures	Fault tree model found winter storm and drought disrupted food systems, making food inaccessible, unavailable, or unacceptable for consumption.	Baltimore DOT and Maryland Transport Administration (winter storm); CA agricultural production data (drought 2013-2017)	✓	a, c	Chodur et al. (2018)
Multiple hazard risks (heat waves and flooding)	Residents of New York City	Community resilience study	Hurricane inundation zones, demographics	Combined vulnerability and multi-hazard risks on map of New York City; suggested prioritizing adaptation and mitigation measures in highest risk coastal areas of Brooklyn, Bronx, and Harlem.	NOAA temperature and precipitation data (Central Park); New York Times (articles day after event); local decision-maker survey; US census data; 311 call data	✓	a, c, e	Depietri et al. (2018)
Weather hazards and community resilience and social vulnerability	Counties in the United States	Community resilience study	Population density and demographics, county resources, civic organizations	Mapped hazard risk and capacity for recovery; high vulnerability correlated with low resilience; Midwest and Northeast more resilient and less vulnerable than South and West.	US Census data and shapefiles, USA Counties website, City & County Data book; NY Times 2008 Presidential election voting data, Association of Religion Data archives	✓	a, c	Bergstrand et al. (2015)
Coastal storm vulnerability	Counties along US Atlantic coast	Community resilience study	Ocean distance, population demographics	Developed Coastal Risk Index with and without natural coastal habitat scenarios; 40% more counties at high risk without natural coastal habitat.	Bio-geo-physical data (natural habitat type, geomorphology, coastal relief, wind and wave exposure, surge potential, elevation); US Atlantic coast historical sea level trends	May be time-consuming, costly, technical	a, c	Sajjad et al. (2020)

Appendix A: Community Resilience Interventions and Metrics with Climate Focus and Health Impact

Climate and Health Focus	Target Population and Location	Study Type	Formative Metrics (Unit Measured)	Summative Metrics (Health-Related Outcomes)	Method/Data Sources	Data Available Locally?	2011 CDC National Standards[a]	Source
Drought recovery	Municipalities across the US	Community resilience study	Water conservation, drought plan	Media more likely to report on short-term emergency-coping responses rather than long-term drought resilience initiatives.	NDMC's Drought Impact Reporter database	✓	c	Jedd, T.M. (2019)
Community disaster resilience	Community partners in Chester County, PA and community members in Coatesville, PA	Social capital and community engagement tool development and pilot	Participation in community groups, trust, connectedness	Piloted COPEWELL Rubric's social capital domain; user's guide needed for community self-assessment.	Participant knowledge and experience on social capital and resilience.	✓	a, b, c, e	Schoch-Spana et al. (2019)
Disaster resilience and social capital	Counties across the US	Community resilience tool	Demographics, civic organizations, political activities	Created Social Capital Index; highest social capital in West and South, lowest in Southwest.	US Census 2010; County Business Patterns 2010; ESRI	✓	c	Kyne & Aldrich (2020)
Disaster preparedness	CDC staff in GA, WV and CO	Community resilience intervention	Preparedness attitudes and behaviors	Emergency preparedness knowledge and community resilience increased.	Ready CDC evaluation and pre-post survey	✓	a, c, d, g	Thomas et al. (2018)
Disaster response & recovery	Counties and parishes in US affected by major disaster in 2011	Community resilience study	Pre-event response and recovery plans, partnerships, training	Pre-event planning, NIMS, ICS, full-scale exercises, and community engagement improved response and recovery outcomes.	Survey of local county emergency managers; 2010 US Census; FEMA regional data	✓	c, e	Zukowski, R. S. (2014)
Disaster recovery	Disaster recovery experts in US	Community engagement tool pilot	Disaster plans, demographics, FEMA funding	Developed online Recovery Indicators Tool; adding spatial data would aid recovery assistance.	Interviews and focus groups with experts; pre-disaster recovery plans; case studies in NJ and NC	Open source data unavailable for some metrics	a, b, c, e, f	Dwyer & Horney (2014)
Disaster preparedness, response, and recovery collaboration	Local health departments and community / faith-based organizations in the US	Community resilience tool	Engaging or collaborating with organizations in trainings and outreach	Piloted ADEPT; higher scores reflected more active relationships with community and faith-based organizations for disaster preparedness, response, and recovery collaboration.	National survey of local health department disaster preparedness coordinators	✓	b, c	Glik et al. (2014)
Disaster communication	Journalists across the US	Community resilience study	Warnings, disaster reports, mitigation information	Journalists facilitated recovery via information and engaging the community; disaster reporting increased stress and depression.	Telephone interviews with US journalists	✓	c	Houston et al. (2019)

Note. Abbreviations include: CDC: Centers for Disease Control and Prevention; RCHC: Resilience and Coping for the Healthcare Community; PTSD: post-traumatic stress disorder; LIGHT: Leaders in Gathering Hope Together; NYC: New York City; PSA: public service announcement; COAST: Creating Optimism After Sandy Trauma; REDI: Resilience to Emergencies and Disasters Index; NYCDCP: New York City Department of City Planning; MTA: Metropolitan Transit Authority; FEMA: Federal Emergency Management Agency; CART: Communities Advancing Resilience Toolkit; COPEWELL: Composite of Post-Event Well-being; DOT: Department of Transportation; NOAA: National Oceanic and Atmospheric Administration; NDMC: National Drought Mitigation Center; ESRI: Environmental Systems Research Institute; NIMS: National Incident Management System; ICS: Incident Command System; ADEPT: Assessment for Disaster Engagement with Partners Tool.

[2]CDC National Standards: a) determining health risks in a community; b) coordinating and strengthening community partnerships; c) sharing information; d) providing preparedness trainings; e) identifying recovery needs; f) supporting recovery operations; and g) implementing actions to mitigate future adverse effects from future incidents.

Appendix B Resource List of Toolkits to Measure Community Resilience

Toolkit	Target Population / Task	Source
Assessment for Disaster Engagement with Partners Toolkit (ADEPT)	Local health departments building community partnerships	Martel et al. (2014) https://cphd.ph.ucla.edu/sites/default/files/downloads/ADEPT%20Toolkit.pdf
Baseline Resilience Indicators for Communities (BRIC)	Health and planning officials comparing communities at the county level using social, economic, community, institutional, infrastructure, and environment resilience indicators; scores available for 2010 and 2015	University of South Carolina College of Arts and Sciences (n.d.) https://artsandsciences.sc.edu/geog/hvri/bric
Building Resilience Against Climate Effects Framework (BRACE)	Health officials assisting communities prepare for climate-related health hazards	Centers for Disease Control and Prevention (2019c) https://www.cdc.gov/climateandhealth/BRACE.htm
Communities Advancing Resilience Toolkit (CART)	Communities self-assessing their capacity for disaster preparedness, prevention, response, and recovery	Pfefferbaum et al. (2011) https://www.oumedicine.com/docs/ad-psychiatry-workfiles/cart_online-final_042012.pdf
Community Assessment for Public Health Emergency Response Toolkit, 3rd edition (CASPER)	Public health and emergency managers assessing community needs at the household level	Centers for Disease Control and Prevention (2020a) https://www.cdc.gov/nceh/casper/default.htm
COPEWELL Rubric Self-Assessment Tools	Communities wanting to self-assess community functioning; population, vulnerability, inequality, and deprivation; prevention and mitigation; social capital and cohesion; emergency management	Johns Hopkins University (2020) https://www.copewellmodel.org/self-assessment-tools.html
PARTNER Tool	Communities assessing community partnerships and networks	Visible Network Labs (2010) https://visiblenetworklabs.com/partner-platform/
Resilience Builder Toolkit	Communities wanting to identify community needs to build a resilience work plan	Chandra et al. (2015b) http://www.laresilience.org/documents/resilience-builder.pdf
Social Vulnerability Index	Local officials wanting to identify vulnerable populations	Agency for Toxic Substances and Disease Registry (2018) https://svi.cdc.gov/
TTM Transtheoretical Model of Behavior Change	Public health officials measuring changes in stages of emergency preparedness actions and attitudes	Pro-Change Behavior Systems Inc. (2018) https://www.prochange.com/transtheoretical-model-of-behavior-change
U.S. Climate Resilience Toolkit	Over 200 tools for communities and local planners to create plans and build resilience	Tools | U.S. Climate Resilience Toolkit (2020) https://toolkit.climate.gov/tools