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by

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Committee in Charge:

Professor Tomás J. Aragón, Co-Chair
Professor Arthur Reingold, Co-Chair
Professor Ann Keller
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ABSTRACT

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While public health threats have always existed, federal investment in preparedness has surged in the past decade. Interested in evaluating return on their investments in public health preparedness, congressional and public stakeholders have pushed for the development of assessment, accountability, and improvement measures. However, the evidence base to support this priority has lagged behind. There is still little agreement on how to measure, let alone improve, public health response performance. A number of challenges have been cited as barriers to research advancements in this field, including the infrequent nature of large-scale public health emergencies, heterogeneity of emergency events and of public health delivery structures, and difficulties gaining access to incident leadership during real-world emergencies. Limitations in our knowledge pose significant barriers to public heath authorities who seek to evaluate their own response capacity and direct resources towards evidence-based improvements. They also hinder stakeholders' ability to develop valid, reliable, and realistic measures to evaluate how well health public health systems are performing. In the case of acute events, the quality of public health performance can make a difference in the number of lives saved, illnesses or injuries averted, and the economic and social costs to a community. Consequently, it is of utmost importance to ensure that the evidence base used to guide the development of standards and measures is the best possible.

This dissertation includes examples of three research initiatives that seek to: (1) improve the public health emergency response evidence base by characterizing key structural and functional dimensions of the response systems during real-world urgent and emergency events, (2) identify factors which influence variation in this system, and (3) demonstrate that advancements in conceptual models of public health response operations are both possible and relevant.

DEDICATION

To Mark: my favorite editor, supporter, friend, and husband.

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This document is evidence of the enormous debt of gratitude that I have accumulated throughout the dissertation process. This is a debt that I know I can only repay through my life's work, by serving others with the kindness, generosity, and integrity that has been modeled for me. Nevertheless, I would like to mention a few individuals who have made notable contributions to this work as well as my own personal and professional development.

First and foremost, to my participants, who shared their experiences responding to public health incidents, which ranged from the unusual, to the mysterious, to the devastating. One incident at a time, these narratives provided an unparalleled education on the public health response system in action. Thank you.

I would also like to thank the members of my dissertation committee – Dr. Tomás J. Aragón, Dr. Arthur Reingold, Dr. Ann Keller, and Dr. Todd LaPorte – for their support, encouragement, and critical feedback throughout this process. My advisor, Dr. Aragón, gave me the flexibility to pursue my own research agenda and the courage to challenge myself while consistently modeling excellence and integrity. It is a rare opportunity to work with an individual whose character and vision inspires others to make the world a better place, and I will carry many lessons learned during this experience throughout my life. Dr. Reingold provided the mentorship and advice that is only possible from someone so distinguished within his field of study. I feel enormously lucky to consider Dr. Reingold as an advisor, and his contributions to my dissertation and learning are enormous. I will always be grateful to Dr. Keller, who simultaneously served on two Hunter dissertation committees, who was an extraordinary chair for my qualifying exam, and who consistently provided insightful feedback on my work, and in doing so substantially contributed to my development as a scholar. Lastly, I want to extend a great deal of appreciation to my outside committee member, Dr. Todd LaPorte, whose contributions to public administration theory are so great that a recent volume of the *Journal of Contingencies in Crisis Management* was fully dedicated as a tribute to the positive influence of his work and mentorship. It is a great honor to have had the privilege to work with, and to be challenged by Professor LaPorte.

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CHAPTER 1: DISSERTATION INTRODUCTION

Background and significance

In 1988 the Institute of Medicine (IOM) published a landmark report, *The Future of Public Health*, which defined public health as "what we, as a society, do collectively to assure the conditions in which people can be healthy" [1]. At its core, this definition demonstrates a recognition that the public's health is a distributed responsibility, and that many entities serve to directly or indirectly influence the health of a community. The unique role of governmental public health, explicated by Childress and colleagues (2002), comes from "its responsibility, grounded in its police powers, to protect the public's health and welfare, because it alone can undertake certain interventions, such as regulation, taxation, and the expenditure of public funds, and because many, perhaps most, public health programs are public goods that cannot be optimally provided if left to individuals or small groups" [2].

As part of their central mission, public health agencies regularly attend to a wide range of disease and health threats, including those that require routine, acute, and emergency responses. In recent years, the anthrax attacks in 2001 and the resulting concerns about bioterrorism, the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003, the extraordinary destruction caused by Hurricane Katrina in 2005, and the threats of a pandemic from novel H5N1 and H1N1 influenza viruses in 2003 and 2009, respectively, provided vivid examples of how natural and man-made phenomenon can wreak havoc on the health and well-being of a community. Public health agencies have received increased attention and visibility following these events, which have been met with both public investments in preparedness as well as heightened expectations of the public health system's ability to prevent, detect, and contain health threats to communities [3].

While public health threats have always existed, federal investment in preparedness has surged in the past decade. The U.S. Department of Health and Human Services first began funding state and local health departments for preparedness in 1999, resulting in a $9 billion investment to-date [4]. Much of this funding has been provided through the CDC Public Health Emergency Preparedness Program (PHEP), authorized in 2002 though the Public Health Security and Bioterrorism Act (Preparedness and Response Act, Pub. L. 107-188) and reauthorized in 2006 through the Public Health All-Hazards Act (Pub. L. 109-417)[3]. Interested in evaluating return on their investments in public health preparedness, congressional and public stakeholders have pushed for the development of assessment, accountability, and improvement measures [5]. However, the evidence base to support this priority has lagged behind. There is still little agreement on how to measure, let alone improve, public health response performance [6, 7]. The causes and consequences of this mismatch are aptly described by Acosta and colleagues (2009), in their recent review of public health preparedness research priorities:

"Improving public health emergency preparedness is at the top of the national agenda, but the lack of frequent opportunities to observe and learn from real-world responses to large-scale public health emergencies has hindered the development of an adequate evidence base. As a result, efforts to develop performance measures and standards, best practices, program guidance, training, and other tools have proceeded without a strong empirical and analytical basis" [6].

These limitations pose serious challenges to public heath authorities who seek to evaluate their own response capacity and direct resources towards evidence-based improvements. They also hinder stakeholders' ability to develop valid, reliable, and realistic measures to evaluate how well health public health systems are performing. In the case of acute events, the quality of public health performance can make a difference in the number of lives saved, illnesses or injuries averted, and the economic and social costs to a community. Consequently, it is of grave importance to ensure that the evidence base used to guide the development of performance standards and measures is the best possible.

The following papers provide examples of three research initiatives that seek to: (1) improve the public health emergency response evidence base by characterizing key structural and functional dimensions of the public health response system and to identify factors which influence variation in this system, and (2) demonstrate that advancements in conceptual models of public health response operations are both possible and relevant.

Conceptual Framework

The three research studies presented in the following chapters are guided by a conceptual framework developed and implemented by Mays *et al.* (2010) in their characterization of the organization and delivery of twenty core public health activities at the local level [8]. Heavily influenced by organizational and economic theory, this framework focuses on three attributes believed to play an important role in influencing performance-relevant variations in service delivery within any system: differentiation, integration, and concentration [8]. In short, this framework proposes that attempts to capture variation in a system should attend to: 1) how diverse are the set of services delivered by the system, 2) how well elaborated are the relationships between actors in the system, and 3) how responsibility is distributed within the system. This systems-based approach seems particularly well suited for public health applications. The framework recognizes that governmental public health agencies work within a complex organizational system to deliver a diverse array of public health services. As in the approach used by Mays and colleagues, I apply the framework to local public health agencies to examine the type and number of activities delivered through the system, and to characterize the extent to which these activities were performed by the health department versus other organizations within the system. The following sections further elucidate the key domains of this framework, their theoretical underpinnings, and their applications to public health emergency response in the studies that follow.

The first concept in this framework is ***differentiation,*** defined by Mays et al (2010) as the "different programs and activities delivered through the system" [8]. Differentiation is influenced by both supply-side factors, such the resources, expertise, and willingness of the local public health agencies to provide services, and demand-side factors, such as the health needs of the community and their preferences and attitudes towards public health interventions [8]. Within the context of this investigation, this concept is defined as the "different public health response activities and functions performed by the public health system" and is referred to as ***public health response activities.***

In our investigations, the CDC Public Health Preparedness Capabilities (PHEP Capabilities) are used as an organizing framework for bounding the understanding of public health action[9]. The PHEP Capabilities, developed through a review of legislative and executive directives, expert panel processes, and extensive stakeholder engagement, identifies and defines 15 types of services (grouped in five domains) that public health systems could be expected to deliver during emergencies. The PHEP Capabilities span a vast terrain of potential public health response activities, ranging from epidemiologic investigation, to delivering medications and vaccines to affected persons, to coordinating public health and medical needs during sheltering operations. However, for any given event, only a subset of PHEP Capabilities might be required or appropriate. The basic idea of differentiation is that our frameworks should capture, for each event, the number and types of response activities that the public health response system provides. Then, looking across events, we might observe patterns in response activities associated with particular types of events. Such patterns do not establish what is necessary for "good performance." The claim is more modest: that any of the key inputs to performance -- plans, training, standards, and guidance -- can be improved through stronger and more realistic models for understanding the services that public health systems deliver during acute events. For example, consider the following two recent real-life, large-scale, public health response efforts, which illustrate how response activities vary as a consequence of the type of hazard faced by the community.

- ***Multi-state outbreak of invasive fungal infections.*** During the 2012-13 multi-state outbreak of fungal meningitis and other invasive fungal infections, illnesses and deaths were linked to a contaminated medical product, injectable steroids, which originated from a single pharmaceutical compounding facility. The public health response involved extensive epidemiologic investigations to determine the source of the outbreak, a coordinated effort to identify and notify the nearly 14,000 potentially exposed patients of their risks, information management activities assure that contaminated products were no longer being used in clinical practice, and intervention steps at the implicated production facility to stop any new products from entering the marketplace [10].
- ***Public health response to tornado in Joplin, Missouri.*** In 2011, a tornado devastated the town Joplin, Missouri, resulting in the rapid destruction of homes and healthcare

facilities, and resulted in thousands of impact injuries. The public health response involved the rapid erection of temporary medical facilities to provide care for those injured by the tornado and patients who were evacuated from affected healthcare facilities, safe shelter for those who had lost their homes, and coordination of volunteers and donated goods to support the medical and health response efforts [11].

Was the response in either case good? We don't know. We can't know because we do not yet have an empirically grounded expectation of what response activities are usually carried out in similar events, must less a knowledge of what activities *should* be. The point of measuring differentiation, the number of different types of activities delivered by the system in each case, is to help develop exactly this type of empirically grounded expectation. With this motivation, we characterize the number and type of public health response activities for many events, examine how these response activities vary based on the type of hazard, and assess whether there are discernable patterns that could improve our expectations for future performance when facing events of a similar nature. Specifically, in Chapters 2 and 3 we look at variation in response with respect to six commonly recognized hazard categories: natural disasters and severe weather, mass casualty events, and incidents involving: infectious diseases, bioterrorism agents, chemicals, and radiation.

Hypothesis #1: The number and type of public health response activities triggered during urgent events will vary with respect to the characteristics of the event (e.g. the public health hazard category).

The second concept in this framework is ***integration***, defined by Mays *et al.* (2010) as, "as the extent to which services are provided through relationships with other organizations" [8]. Integration relates to the number of organizations contributing to the delivery of public health services and is influenced by both the availability of organizations in a community able to assist or contribute to public health activities and their incentives to do so (e.g. economic, regulatory, altruistic) [8]. For the following three investigations, the concept of integration was modified in order to characterize the organizational composition of the ***public health response system,*** defined as the number and type of organizations contributing to the public health response activities. As can observed in the vignettes described above, the public health response system delivers its activities through a variety of organizations, not just the local health department. For example, in the case of the fungal meningitis outbreak, a clinician from the community alerted the Tennessee Department of Health about a patient with an uncommon form of meningitis, a finding that was quickly relayed to the CDC. Soon, state and local public health agencies throughout the country were involved in the response, each working with hospitals, health care providers, laboratories, and exposed persons within their communities. In Massachusetts, public health agencies worked closely with the Food and Drug Administration to investigate sources of contamination at the implicated production facility and to implement control measures [10].

The motivation for studying integration parallels that described for differentiation. Capturing, for each event, the number and type of partners, will allow for the improvement of key inputs to performance -- the same plans, trainings, standards and guidance -- by improving our expectations about what types of agencies actually deliver specific services during acute events. If our first hypothesis is correct, when we pool response information from many cases, we anticipate that the number and type of organizations that contribute to the public health response would also vary based on the type of hazard, particularly because each distinct public health capability is expected to require different sets of expertise and resources. To see how this knowledge could inform performance, consider a preparedness director, trying to negotiate memoranda of understanding with potential community partners. If we are able to identify any patterns, a local public health agency could use this information could secure “buy in” from those partners by presenting them with the *specific scenarios* in which they are most likely to take part. Exercises or trainings could be focused on such events or, alternatively, on less frequently occurring ones.

Hypothesis #2: The number and type of public health response partners activated during urgent events will vary with respect to the characteristics of the event (e.g. the public health hazard category).

The last domain described in this framework is ***concentration*,** which is defined by Mays et al (2010) as “how public health responsibilities are distributed among these participating organizations” [8]. For the following three investigations, the concept of concentration is referred to as ***the role of public health***, which defines the relative position of public health agencies’ responsibility and effort with respect to the overall response efforts. A highly concentrated system is one in which governmental public health serves in the lead role in the public health response and a less concentrated system would be one in which another agency shoulders most of the responsibility for the overall response and public health serves in supporting role. Again, as illustrated through the vignettes above, the public health response system delivers its activities within the broader context of the response efforts. In the case of the tornado, the public health response was one of many emergency response efforts, working under the direction of emergency management to restore community services, including: electricity, transportation, security, and continuity of government. In contrast, the fungal meningitis outbreak provides an example in which the public health hazard and the public health response were the primary and central concerns. As a result, public health agencies would be expected to serve in a lead role within the response system.

The motivation for studying concentration parallels that described for the other domains in this framework. Characterizing, for each event, the role of public health, will also allow for the improvement of key inputs to performance -- the same plans, trainings, standards and guidance -- by improving our expectations about how “central,” and thus in some sense how “responsible” public health departments are to how response activities unfold. By looking across many cases, we anticipate that role of public health agencies will also vary based on the type of hazard. From a planning perspective, demonstrated patterns in the role of public health could inform performance by allowing preparedness coordinators to further develop a mutual understanding regarding the circumstances in which public health might be expected to serve in a lead or supporting response role. By focusing on which agency will be expected to shoulder the greatest responsibility prior to an event, this domain may be particularly important in reducing conflict during an event regarding "who is in charge". Multi-year exercise plans might, then, alternate scenarios based on the expected role of public health – allowing for varied opportunities for learning and reinforcing expectations.

Hypothesis #3: The role of local public health agency within a response system will vary with respect to the characteristics of the event (e.g. the public health hazard category).

Significance

This dissertation contributes to the field of public health preparedness in a number of ways. It first demonstrates that despite the recognized challenges in public health preparedness research, it is possible to identify structural and functional inputs to public health system performance and to recognize factors that influence variation in patterns of response system activation. Second, the findings resulting from this approach have direct relevance for practice and policy. For example, by examining data across many events uncommonly experienced in any single community, we provide health department managers with improved opportunities for learning. The response patterns highlighted in our findings provide data that would otherwise not be available at the local level, potentially providing new approaches or rationales for preparedness decisions, including how to allocate resources, develop training programs or policies, or engage potential response partners. For policy makers, this research establishes that it is feasible to build future guidance and standards on better practice-based evidence.

Organization of the dissertation

This dissertation includes three research studies, described below, each of which explores the structural and functional characteristics of the public health response system during real-world events. The dissertation ends with a brief conclusion that highlights a few key findings that demonstrate the nature of insights that are possible through research and the relevance of this research for policy, particularly with respect to future guidance and accountability efforts.

Chapter 2: Public health response systems in action: A structured review of "urgent event" case reports. Using the published literature from the CDC publication *Morbidity and Mortality Weekly Report* as its case material, this study examines and characterizes the public health activities and partners that were involved in the response to 128 distinct incidents in the United States and how these response features vary as a function of event characteristics.

Chapter 3: Public health systems in action: Learning from health departments' experiences with acute and emergency incidents. Using telephone-based structured interviews with local health department representatives in the United States as case material, this study examines and characterizes which public health activities and partners that were involved in the response to 123 distinct incidents and how these response features vary as a function of event and organizational characteristics.

Chapter 4: Public health management of antiviral drugs during the 2009 H1N1 influenza pandemic: A survey of local health departments in California. Using a web-based survey of local health department representatives in California, this study examines the public health response to the 2009 H1N1 influenza pandemic, focusing on one response activity, antiviral management, in detail.

References

1. Institute of Medicine (IOM): *The Future of Public Health*. National Academy Press; 1988.

2. Childress JF, Faden RR, Gaare RD, Gostin LO, Kahn J, Bonnie RJ, Kass NE, Mastroianni AC, Moreno JD, Nieburg P: **Public Health Ethics: Mapping the Terrain**. *J Law Med Ethics* 2002, **30**:170–178.

3. U.S. Senate: *Pandemic and All-Hazards Preparedness Act. Report [to accompany S. 3678]*. 2006:109–319.

4. Trust for America's Health: *Ready or Not? Protecting the Public from Diseases, Disasters, and Bioterrorism*. Robert Wood Johnson Foundation; 2012.

5. U.S. Centers for Disease Control (CDC): **Preparedness and Emergency Response Research Centers: A Public Health Systems Approach (P01). RFA-TP-08-001.** 2008.

6. Acosta J, Nelson C, Beckjord E, Shelton S, Murphy E, Leuschner KJ, Wasserman J: *A National Agenda for Public Health Systems Research on Emergency Preparedness*. RAND Corporation; 2009.

7. Asch SM, Stoto M, Mendes M, Valdez RB, Gallagher ME, Halverson P, Lurie N: **A review of instruments assessing public health preparedness.** *Public Health Rep* 2005, **120**:532–542.

8. Mays GP, Scutchfield FD, Bhandari MW, Smith SA: **Understanding the Organization of Public Health Delivery Systems: An Empirical Typology**. *Milbank Q* 2010, **88**:81–111.

9. U.S. Centers for Disease Control and Prevention (CDC): *Public Health Preparedness Capabilities: National Standards for State and Local Planning*. 2011.

10. Bell BP KR: **Responding to the outbreak of invasive fungal infections: The value of public health to Americans**. *JAMA-J Am Med Assoc* 2013:1–2.

11. Friel M, Smith DS, Harmon C: **A Community Comes Together: Rebuilding the Public Health and Healthcare System after the Joplin, Missouri, Tornado**. In *Public Health Prepaedness Summit*. Anaheim, CA: 2012.

Chapter 2: Public health response systems in action: A structured review of "urgent event" case reports

"Improving public health emergency preparedness is at the top of the national agenda, but the lack of frequent opportunities to observe and learn from real-world responses to large-scale public health emergencies has hindered the development of an adequate evidence base. As a result, efforts to develop performance measures and standards, best practices, program guidance, training, and other tools have proceeded without a strong empirical and analytical basis" [1].

Introduction

As part of their central mission, public health agencies attend to a wide range of health threats, including those that require routine, urgent, or emergency responses. Events that grip the headlines serve as important reminders of the need for robust and adaptable public health preparedness systems that can respond, regardless of the threat – from a small outbreak affecting a localized area, to a regional natural disaster, to a nationwide public health emergency. Improving the preparedness of public health systems has emerged as a national priority, with public health agencies receiving billions of dollars in funding for these purposes over the past decade [2].

Despite widespread consensus regarding the importance of preparedness for a public health emergency, there is little agreement on how to measure and improve response performance [1, 3]. A critical gap in the evidence base is a basic description of how response systems function during real-world incidents. The vast majority of the measurement literature in this field focuses on preparedness rather than response -- on identifying and measuring the inputs to preparedness rather than the variations in response performance. In fact, much of what we know about public health emergency response is derived from simulated emergencies (e.g. exercises or drills) with a primary focus on bioterrorism or pandemic influenza [1]. By relying on an evidence base that draws from a narrow set of threats, we risk the possibility of overemphasizing the capabilities and resources required for those incidents while neglecting those that may be essential in other scenarios [4].

A number of challenges have been cited as barriers to public health emergency response measurement and improvement, including the infrequent nature of large scale-public health events, the heterogeneity of emergency events and of public health delivery structures, and the difficulty of identifying a comparison group or constructing a counterfactual [1, 5, 6]. As a result, researchers have been limited in their use of statistical methods to test hypotheses, reach generalizable conclusions, and isolate factors that have the greatest impact on response capacity.

Despite the complexities of studying public health emergencies, a small but growing body of literature has brought public health *response to real incidents* into focus, including the role of public health in events ranging from Hurricane Katrina, mass shootings at Virgina Tech, widespread blackouts in New York City, and the emergence of West Nile Virus [7–10]. Using qualitative methods, such as case studies, case series, and root cause analyses, this research begins to capture the richness of data available in rare events, following the traditions of other social science disciplines that study infrequent events [11]. With these methods, researchers have also begun to examine smaller incidents, such as a localized outbreak of hepatitis A infections, which occur more frequently and are expected to elicit response activities and produce challenges that may result in relevant findings for larger-scale emergencies [9, 12, 13].

By shifting the focus *from preparedness to response* and *from catastrophic events to smaller events*, the number of opportunities for learning is vastly increased. Using a more quantitative approach, it is possible to pool data on real-world incidents from diverse contexts [10, 14, 15]. Guiding this research is a belief that while each event is unique, studying responses to many events may provide valuable insights on key similarities and differences that can inform future research. Though much of the qualitative richness is lost in this approach, what is gained is the potential to observe patterns, develop hypotheses on response behavior and outcomes that may be applicable in a number of settings, and improve the precision of emergency response questions in future research. As such, we view this approach to be complementary to the more in-depth analysis. Rather than asking, "what were the lessons learned?" from an event, we might be able to produce evidenced-based predictions for a given event or health department structure. As a result, deviations from expectations provide opportunities to improve incrementally our understanding of response performance. These "surprises" may point to: (1) lack of sophistication in our models, (2) adaptive response behaviors, or promising practices, that could be applied in other situations to positive effect, or (3) unnecessary variation associated with inefficiencies that may affect the health of a community or the reputation of public health agencies. Regardless of the outcome, the prior expectations generated through exploratory research allow us to learn more when opportunities present themselves.

Using a new definition of "urgent public health events," our study leverages the experiences of health departments across the United States to examine retrospectively the structures and functions of public health response systems during real-world incidents. Situated in the "all emergencies are local" perspective, we take a local lens, focusing on both larger and smaller events that meet the following definition: *a sudden, unexpected, imminent, or potential (1) exposure to a hazardous state or substance, (2) increase in illness or disease severity, or (3) loss of public health prevention measures, which compels rapid and/or intensive action in an effort to mitigate, control, or prevent expected adverse heath or economic consequences*. Case studies reported in the Morbidity and Mortality Weekly Report, a Centers for Disease Control and Prevention (CDC) publication, are the subject of this investigation. Using these reports, we retrospectively examine key aspects of the event, the public health response activities, and the organizational entities that contributed to those activities. Additionally, we begin to examine how variations in context may influence the character of the response by examining two categories of incidents, infectious disease and non-infectious disease events. The goals of this study are:

- To describe the characteristics of urgent events that elicit a public health response;
- To examine the types of public health activities that are initiated in response to urgent events and the types of organizations that contribute to these activities; and
- To explore how public health activities and system partners differ in two types of contexts: infectious disease and non-infectious disease events; and
- To provide baseline data for generating hypotheses regarding the organizational or contextual factors that influence public health urgent and emergency response performance.

Method

Study Design

This research uses a systematic review of urgent event case reports from the CDC publication *Morbidity and Mortality Weekly Report*.

Study Population

One of the primary aims of this investigation is to characterize how public health agencies and their community partners respond to urgent and emergency events at the local level. Because no comprehensive data source of such events exists, we turned to the published literature to examine what can be learned from publicly available case reports. *MMWR* was selected because it regularly publishes reports of urgent and emergency public health events and because these reports provide detail on the measures of interest: context of the event, the public health investigation, and the public health response. Instructions to authors indicate that "events of concern include epidemics/outbreaks, unusual disease clusters, poisonings, exposures to disease or disease agents (including environmental and toxic), and notable public health-related case reports." Therefore, we expected that the scope of reports in the *MMWR* would satisfy our goal of collecting case reports on infectious disease and non-infectious disease events.

The process for selecting case reports for this structured review involved three steps: searching for and identifying records, screening titles, and assessing full-text articles for eligibility [16]. Records were first identified through PubMed using the following search terms: *"MMWR. Morbidity and mortality weekly report"[Journal] AND ("2007/01/01"[PDAT] : "2011/12/31"[PDAT])*, which limited the search to all published MMWR records from January 01, 2007 through December 31, 2011. The titles of these records were then screened to assess whether they appeared to summarize a public health response to an urgent event. We define an urgent event as a sudden, unexpected, imminent, or potential (1) exposure to a hazardous state or substance, (2) increase in illness or disease severity, or (3) loss of public health prevention measures, which compels rapid and/or intensive action in an effort to mitigate, control, or prevent expected adverse heath or economic consequences. Full-text articles of those records appearing to meet the screening criteria were assessed for eligibility. Our inclusion criteria required that all case reports must: focus on an urgent or emergency public health event, provide detail on the overall public health response, have involvement of a state or local public health department in the United States, and have been published in *MMWR* during five-year period of January 1, 2007 and December 31, 2011. Due to the large number of case reports focusing on the 2009 H1N1 influenza response and the potential for these reports to skew our results towards this single scenario, we decided to exclude these case reports from this sample. For reports meeting the inclusion criteria, a standardized data abstraction tool was used as a systematic approach to collecting key data elements related to the event, response activities, and public health system characteristics. This tool is available in the **Appendix.**

Measures

The response measures selected for this investigation were informed by a prior study of the organization and delivery of local public health services during normal operations; these measures were employed in that study because they could reasonably be expected to influence performance and outcomes [17, 18]. These measures were modified for use in a public health emergency response context. Using an epidemiologic lens, we view these response measures as intermediate outcomes between the phenomenon of interest (an urgent event) and the final outcomes of interest (e.g. exposures, illness, disability, death)[19].

Event characteristics. Each report was characterized with respect to a number of event features, which were selected with the goal of building a common operational picture that allowed for meaningful comparison across disparate events. The selection of event features was further constrained by the elements that are routinely identified within MMWR reports. Accordingly, each report was assigned to one of six specific hazard categories, as defined by the CDC Emergency Preparedness and Response website, including: infectious disease outbreaks and incidents, natural disaster or severe weather events, bioterrorism events, mass casualty events, chemical emergency events, and radiation emergency events [20]. An additional "other" category was developed for reports that could not easily be categorized in the initial six hazard categories. For the purpose of certain analyses within this investigation, these categories were further collapsed into two groups, (1) infectious disease events, including bioterrorism and infectious disease outbreak events, and (2) non-infectious disease event, comprising the remaining hazard categories. Additional hazard details were collected, as appropriate for each category. For infectious disease events, the disease agent and mode of transmission were recorded, whereas for severe weather or natural disaster events, the type of severe weather event was noted (e.g. hurricane, flooding, severe winter weather). For all reports, regardless of the hazard category, the following event details were summarized: the duration of the public health response, the number of individuals contacted as a part of the investigation of the illness or exposure, the number of probable or confirmed cases, the number of severe cases (requiring hospitalization or resulting in death), and the number of persons receiving medical countermeasures as part of the public health response. Additionally, for each report, the geographic location and populations most affected by the event were also identified.

Public health response activities. We used the CDC Public Health Preparedness Capabilities (PHEP Capabilities) framework and definitions as the basis for characterizing the public health activities carried out in response to the hazard [21]. This framework, developed through a review of legislative and executive directives, expert panel processes, and extensive stakeholder engagement, identifies and defines 15 types of services that public health systems could be expected to deliver during emergencies. We deviated from this this framework for data collection in two key ways. Whereas CDC includes "environmental investigation" activities within the public health surveillance and epidemiology capability, we decided to look at these activities separately because the expertise required for conducting environmental investigations and the type of events that elicit environmental investigations differs substantively from that required for epidemiologic investigations. By examining environmental and epidemiologic investigations, we are better able to examine these hypothesized differences. For the purpose of this research, environmental investigations are defined as, "the assessment of environmental conditions relating to human health, including food, water, air, shelter and waste." However, in accordance with the PHEP Capabilities framework, the *laboratory testing* aspect of an environmental investigation (e.g. testing water samples) was included within the laboratory capability. The second major deviation from the PHEP Capabilities framework was the collection of "other" activities that did not clearly align with the CDC's characterization of public health response activities and could, therefore, serve as an assessment of the extent to which the PHEP Capabilities characterize the public health response activities described in the case reports. Using the structured data collection instrument, each case report was reviewed to determine the presence or absence of response activities related to the 16 capabilities. These dichotomous variables were used to develop a summary score, which provides the total number of public health response activities initiated in a case report (between 0 and 16 activities).

Organizational partners. The organizations and agencies contributing to the public health response activities were recorded on the structured data collection tool, using an initial list of 35 potential entities. This list was derived from CDC PHEP reporting requirements and the literature describing public health system characteristics, and was iteratively revised throughout the review, resulting in 41 possible organizational categories [17, 22–24]. Once the final list was developed, all reports were reviewed again to ensure consistency (a description of the organization types and categorization process is available in the **Appendix**). Three measures were developed from these data. The first measure, "any involvement", is a dichotomous variable that indicates whether entities from each of the 41 organizational categories contributed to *any* of the 16 PHEP-defined public health response activities. The second measure, "extent of involvement", provides a proportion of the public health response activities contributed by each type of organization. For each case in which a specific organization had any involvement, the "extent of involvement" was calculated as the:

$$Extent\ of\ Involvement = \frac{Number\ of\ PHEP\ Activities\ Contributed\ by\ Each\ Organization\ Type}{Total\ number\ of\ PHEP\ Activities\ Performed\ during\ Urgent\ Event}$$

Additionally, a summary measure of the total number of organizational categories mentioned in the report was calculated (between 0 and 41 organizations).

Variations on case reports

Due to variation in case report structures and reporting authors, not all cases were written from the perspective of a single locality, and therefore include information on the event and the response measures from multiple local jurisdictions. In these instances, we aggregated the data reported by all jurisdictions within a single case report and reported on these aggregate measures.

Statistical Analysis

Data were managed in Qualtrics, downloaded for analysis using Stata 11 (StataCorp LP, College Station, TX), and merged with data from the 2010 NACCHO Profile of Local Health Departments, a national survey on infrastructure and public health practices at the local level [25]. Descriptive statistics for the event characteristics, response activities, and response partners were calculated. For event and response measures, the differences between infectious disease and non-infectious disease events were assessed using *t* tests or chi-square tests, as appropriate.

Based on our power analyses we decided to collect data on a sample of about 120 cases. With this sample size, we expected to have power of 0.8 to detect significant differences of 25 points or more between infectious disease and non-infectious disease events for the response measures of interest (assuming that case reports of infectious disease events were three times more common than non-infectious disease events).

Results

Literature Review

In total, 128 case reports were included in the systematic review. Among the 882 records originally identified through the PubMed search, 207 met the screening criteria and full-text reports were assessed for inclusion. Of the 79 reports excluded after full-text review, the three most common reasons for exclusion were: that the report described surveillance trends only (n=23), focused on the clinical response and did not describe the public health response in detail (n=20), or described a response to the 2009-10 H1N1 influenza pandemic (n=17). The case report selection process is summarized in **Figure 1.**

Public health agency characteristics

The case reports described in our review of urgent events involve communities from 42 US states (**Figure 2**). These states have varying public health governance structures, including those where local public health is governed at the local level (69% of case reports), at the state level (8% of case reports), and states with shared or mixed governance (11%) [25, 26]. The remaining case reports included multiple public health agencies with governance structures in two or more of the stated categories.

Not all case reports named the specific local jurisdiction(s) at the center of the public health response. Of the 57 named local jurisdictions, the median population size served by the corresponding local health department was 426,276 (mean: 984,278 individuals). These health departments had a median of 179 Full-Time Equivalent (FTE) staff members (mean: 547), with a median health department expenditure of $48 per capita (mean: $75 per capita) [25].

Event Characteristics

The final data set includes case reports describing infectious disease events (n=101), chemical events (n=16), events involving a biological agent (n=7), severe weather or natural disaster events (n=3), and an event of unknown etiology (n=1). None of these case reports could be classified as a radiation event or a mass casualty event. For each event category, additional details on the type and frequency of cases are provided in **Table 1**.

Health department's responses varied widely (**Table 2**). Of the 90 case reports in which the duration of the response could be ascertained, public health agencies were involved in response activities for a median of 30 days (mean: 111 days), defined as the number of days from the point in time when public health became aware of the health issue until the final public health activity was completed. A median of 66 individuals were contacted to investigate illness or exposure (mean: 869), resulting in the identification of a median of 9 probable or confirmed cases (mean: 101), and a median of 1 case that resulted in hospitalization or death (mean: 19). A median of zero individuals received medications or vaccines for post-exposure prophylaxis (PEP); however, on average 92 individuals received such PEP. Due to extreme outliers, the median values are expected to provide a more useful measure of the central tendency of these data. A t-test comparison of the log-transformed variable, *individuals contacted to investigate illness or injury*, revealed a borderline significant difference between case reports describing infectious disease and non-infectious disease events, with infectious disease case reports describing a greater number of cases investigated ($p<0.06$).

Public Health Response Activities

According to the case reports, the public health system performed response activities in a mean of 5 PHEP capability categories (range: 2-8 PHEP capabilities). Response activities initiated in more than half of case reports were those related to: public health surveillance and epidemiologic investigations (100% of reports), information sharing (97% of reports), public health laboratory testing (88% of reports), non-pharmaceutical interventions (63% of reports), and environmental or product investigations (52% of reports), **Table 3.** The mean number of response activity categories did not differ between infectious and non-infectious disease events; however, certain activities were more likely in infectious disease events. Specifically, we found that case reports concerning infectious disease events were significantly more likely to mention activities related to public health laboratory testing and dispensing of medical countermeasures, compared to non-infectious disease events ($p<0.05$).

"Other" response activities that were not easily categorized within the PHEP framework included: filing legal actions, assessing breaches of protocol, developing a new surveillance program and training partners in implementation, conducting case management activities (e.g. directly observed therapy), financial accounting of cost of response and related record keeping, and obtaining appropriate care for young children while parents are incapacitated.

Public Health Response System

Case reports mentioned contributions by 31 of the 41 possible organization types. We found that a mean of five types of organizations contributed to public health response activities (range: 1-10). Types of organization types mentioned in more than half of the cases included: state public health agency (87% of cases), local health department (73% of reports), healthcare providers (73% of reports), CDC (69% of reports), and the general public – including cases, family members or contacts of cases, and other members of the public (51% of cases), **Figure 3.** The mean number of organization types did not differ between infectious and non-infectious disease events; however, we found differences in the types of contributing organizations. Case reports on infectious disease events were significantly more likely to mention involvement of state public health agencies and the CDC, compared to non-infectious disease events ($p<0.05$). In contrast, case reports on non-infectious disease events were significantly more likely to mention involvement of first responders (EMS, fire, HazMat), law enforcement or public safety agencies, emergency management, poison control, mental health or agencies serving vulnerable populations, and media ($p<0.05$). With respect to public health governance structure, case reports involving states in which the authority is centralized at the state level or shared with the state were much less likely to identify the local health department as a member of the response system, when compared to states in which the local health department is governed by local authorities ($p<0.05$).

For each case report, we also calculated the *extent of involvement*, or the proportion of initiated PHEP activities for which an agency contributed (if involved), **Figure 3**. This measure is meant to draw attention to examples of organizations that were not often involved, but made substantial contributions when activated. In this analysis we find many instances in which such organizations were involved, most notably: universities/academic institutions, environmental and natural resources agencies, disaster relief agencies, volunteer groups, persons from political or public administration offices, regional health and medical entities, and vector control agencies. Additionally, other organization types were frequently involved, but appear to have served a limited number of functions, including: healthcare providers and general public.

We also examined the organization types that contributed to environmental investigations compared to surveillance and epidemiology investigations. We found that while local and state public health agencies commonly contributed to both types of activities, these health agencies were significantly more likely to participate in surveillance and epidemiology activities ($p<0.05$). In contrast, food and agriculture agencies contributed to 33% of case reports involving environmental investigations in comparison to only 9% of those involving epidemiologic and surveillance investigations, a significant difference ($p<0.05$).

Discussion

Key findings

Focusing on "urgent events" represents a shift in the dominant paradigm of appropriate case material for public health emergency research. By focusing on "urgent events," we expose a valuable source of data that has been hiding in plain view and demonstrate how, by thinking smaller, we may be able to overcome some of the well-characterized limitations of public health emergency research. Additionally, we hypothesize that by building the evidence through examinations of these more frequent and numerous events, we will can ask better questions during larger emergencies.

From this review, we have identified a set of "core" activities and partners that were frequently activated, regardless of event type, as well as a set of context-specific activities and partner organizations that were more commonly triggered by either infectious disease or non-infectious disease events. The typical response partners cited in our case reports corroborate previously published descriptions of the public health system, noting frequent contributions from local, state, and federal public health agencies, healthcare providers, and the general public [17, 24]. We also identified several organizations whose roles are not as well characterized in the public health systems literature (e.g. poison control, mental health and social welfare agencies). Our findings show that infectious disease events were more likely to include these "typical" response partners while non-infectious disease events were significantly more likely to mention involvement of less typical partners, including: first responders (EMS, fire, hazmat), emergency management agencies, law enforcement and public safety agencies, poison control, mental health and agencies serving vulnerable populations, and the media. These results have potential implications for both practitioners and researchers.

These findings can assist health departments to develop customized training and exercise programs. By identifying a combination of scenarios expected to trigger different capabilities and partners, agencies can better ensure that exercises and drills provide varied and complementary opportunities for learning – as a result, preparedness exercises may continue to provide a meaningful chance for training and assessment with less "exercise fatigue" from overworking certain response activities or organizations. Similarly, grounding exercise scenarios in real-world events may increase the enthusiasm of potential response partners who are less typically involved in public health activities and who have difficulty conceptualizing their role in urgent public health events. Through this practice-based learning, jurisdictions could more readily benefit from the experiences of other parts of the country, a recognized gap in disaster preparedness [10].

These findings, from a research perspective, could be of interest in a number of disciplines. One area, in particular, is complexity science. Public health systems have previously been described as "complex adaptive systems"; however, this classification has yet to be examined empirically, as it has in disaster response more generally [27, 28]. As defined by Bovaird (2008), "complex adaptive systems" are characterized by a self-organizing network of organizations, comprised of a number of diverse organizations, in which power and control are highly dispersed, and where organizations are highly interconnected [29]. Using aspects of this definition, our findings suggest that, on the whole, non-infectious disease events frequently elicit response systems with a *more diverse set of organizations*, and, therefore, may be considered more complex than non-infectious disease events. One important implication of these findings is that responders in events involving particularly complex systems may be expected to experience predictable challenges to communication and coordination [30]. Public health preparedness could, therefore, benefit from researchers who study organizational systems with similar characteristics in other disciplines, who may be able to help build expectations around the character of these challenges, their consequences, and strategies for avoiding critical failure points during urgent events.

Additionally, we found several response activities that could not be easily categorized using the PHEP framework. This finding could be of use in updating the framework to more fully capture the full spectrum of responsibilities that public health agencies face during urgent events.

On the appropriateness of using MMWR as a source for case reports

The case reports available through MMWR represent a valuable source of data on the activities of public health response systems. From a review of five years of publicly available data, we identified over 120 reports that met our criteria for an urgent public health event. However, our findings are likely influenced by a significant publication bias, resulting in an underrepresentation of certain types of events and health departments. With respect to event bias, a national survey of local health departments in 2010 found that, approximately half of all agencies had responded to an "all-hazard" event in the previous year (excluding H1N1 influenza). Of these agencies, 23% responded to a natural disaster. In contrast, natural disasters comprised only 2% of the case reports reviewed [25]. As a result, the findings from our analysis may be most relevant to public health functions and structures most activated in response to infectious disease and chemical events. Possibly, as a result, we identified very few case reports describing activities related to mass care and sheltering and no cases reports mentioning volunteer management and medical surge – capabilities likely to have relevance during natural disasters. We have no way of knowing how these functions might affect the structure of the public health system (i.e. mass care and sheltering activities may introduce entirely new organizations or place a greater emphasis on organizations identified in existing case reports). Overall, with only 20 case reports focusing on non-infectious disease events, comprised mostly of chemical events, we do not have much confidence that these events are representative of non-infectious disease events more generally. However, our results are suggestive of ways in which some non-infectious disease events differ from those with an infectious etiology, which can serve as a basis of future study. Second, case reports obtained from the MMWR are much more likely to describe response activities carried out by health departments serving large populations. Because many local entities are not reported by name, we do not have the ability to assess whether these response measures differ by the population size served by the health department

Public health governance structures and local health department involvement

Our results reveal important variation in the organizational composition of the public health system in states with a centralized public health governance structure compared to those in which the local health department is governed by local authorities. Case reports involving states in which the authority is centralized at the state level or shared with the state were much less likely to identify the local health department as a member of the response system. It is unclear whether local health departments were not identified as response partners because (1) they were not involved or (2) because they are not seen as actors independent of the state health department and are therefore considered to be part of the state public health workforce (e.g. employed by the state). We hypothesize that our measures of local health department involvement in urgent public health responses underestimate their true contribution. Of note, because we sought to take a local perspective, our research team initially excluded articles that did not mention any involvement by a local health department. We later recognized that this initial exclusion criterion could result in a selection bias, favoring reports from decentralized health department. By expanding the criteria to include articles with state or local involvement, as we did in the final review, we were able to confirm the existence of this bias. This serves as a cautionary tale to other researchers and helps us to better interpret our findings more accurately.

Strengths

One of the main strengths of this study is the adoption of an “urgent event” definition, thereby greatly expanding the available case material on public health responses at a relatively low cost. By pooling data across cases with different contexts, we had a sufficient sample size to examine patterns, highlight commonalities and differences across events with different contexts and generate hypotheses for future study. Our approach also draws strength from the application of a systems-based and functions-based approach, both seen as essential features of high-quality research in this field [1]. Additionally, using the CDC Public Health Preparedness capabilities as a framework for conceptualizing public health activities, we hoped to be able to contribute to the literature in a way that is standardized and that allows for comparison with future research.

Furthermore, by building the evidence base for public health emergency research, this research aligns with the National Health Security objective of "ensuring that all systems that support national health security are based on the best available science, evaluation, and quality improvement methods" and the Institute of Medicine (IOM) recommendation to "enhance the usefulness of training" by using real events to clarify the roles and responsibilities of organizations and agencies that contribute to public health emergency preparedness and response systems [31, 32].

Limitations

In relying on case reports from MMWR for our data source, we introduce a number of limitations in addition to those described above. Case reports are written with varying levels of detail about the public health response features; therefore, we suspect that our findings underestimate the number and type of response activities and partners. If, for some reason, report completeness differs by event type, this could introduce an important source of bias that would affect our interpretation of associated comparisons. By looking exclusively at written reports, we were unable to clarify the meaning of specific statements. For example, reports often stated that a "public health agency" carried out a specific task. Without the opportunity for follow-up, we were unable to determine whether the action was carried out by a local, state, or federal agency. Ultimately, we resorted to coding these agencies as "public health agency, not specified." This approach likely resulted in an underestimate of public health agency involvement at one or more levels of government. Finally, not all case reports focus on an urgent event from the perspective of a single local health department, with some case reports describing the experiences of several localities (e.g. contaminated food distributed to grocery stores in three counties, each with its own response efforts). Under these circumstances, we aggregated the event response measures into one entry, which may have made events and responses appear more complex than they would be from the perspective of any single locality. These types of case reports were more common in reports about infectious disease events.

Another limitation of this study stems from the broad comparison of infectious disease to non-infectious disease events. Because these categories are quite heterogeneous, important differences in the functional characteristics of certain events may be imperceptible when combined with other events with diverging response profiles. For this reason, it would be interesting to compare a greater number of more homogeneous event categories, such as those described in Table 1. In this investigation, we did not have sufficient number of cases in each of the event categories to make these comparisons. Another approach, which is outside the scope of this project, would be to group events into categories based on the response measures using cluster analysis. This assessment might show how certain types of events elicit response structures that deviate from traditional categories (infectious disease, chemical event, radiation event, etc.).

In addition to MMWR, other publications were explored through both PubMed and Google Scholar as potential sources of case material; however, these searches produced very few articles meeting our inclusion criteria and tended to focus on either public health preparedness activities (e.g. training for emergency preparedness) or a specific aspect of a response (e.g. the impact of school closure on influenza transmission). We felt that the relative benefit of including these additional cases was outweighed by the variability that would be introduced by including article from different journals with various reporting structures and audiences.

Finally, it important to mention that, although studying urgent events may reveal important lessons that are applicable in a catastrophic disaster, we do not recommend pursuing this line of inquiry at the cost of disaster research and training. There are many ways in which disasters are not like urgent events, including extreme loss of life and community infrastructure, and it is essential that we continue preparedness for events of this severity.

Next steps

Looking ahead, we recommend that our definition of "urgent events" be critiqued, refined, and applied in other situations. In order to obtain a more diverse set of cases and to ascertain more complete data, we are also conducting a parallel study featuring the same event and response measures, but using structured interviews with local health department personnel as the source of data. The results of that investigation will be compared with the findings presented in this report to better assess sources of bias. Ultimately, we would like to be able to link our measures with final performance measures, a necessary step for truly understanding which preparedness and response efforts result in better outcomes.

References

1. Acosta J, Nelson C, Beckjord E, Shelton S, Murphy E, Leuschner KJ, Wasserman J: *A National Agenda for Public Health Systems Research on Emergency Preparedness*. RAND Corporation; 2009.

2. Trust for America's Health: *Ready or Not - Protecting the Public's Health from Disease, Disasters, and Bioterrorism*. 2010.

3. Asch SM, Stoto M, Mendes M, Valdez RB, Gallagher ME, Halverson P, Lurie N: **A review of instruments assessing public health preparedness.** *Public Health Rep* 2005, **120**:532–542.

4. Nelson CD, Willis HH, Chan EW, Shelton SR, Parker AM: **Federal Initiative Increases Community Preparedness For Public Health Emergencies.** *Health Affair* 2010, **29**:2286 –2293.

5. Nelson C, Lurie N, Wasserman J: **Assessing Public Health Emergency Preparedness: Concepts, Tools, and Challenges**. *RAND Corporation* 2007.

6. Lurie N, Wasserman J, Nelson CD: **Public health preparedness: Evolution or revolution?** *Health Affair* 2006, **25**:935.

7. Kaplowitz L, Reece M, Hershey JH, Gilbert CM, Subbarao I: **Regional health system response to the Virginia Tech mass casualty incident**. *Disaster Med Public Health Prep* 2007, **1**:S9–13.

8. Beatty ME, Phelps S, Rohner C, Weisfuse I: **Blackout of 2003: public health effects and emergency response**. *Public Health Rep* 2006, **121**:36.

9. Stoto MA, Dausey DJ, Davis LM, Leuschner K, Lurie N, Myers S, Olmsted S, Ricci K, Ridgely MS, Sloss EM, others: **Learning from experience: the public health response to West Nile virus, SARS, monkeypox, and hepatitis A outbreaks in the United States**. *RAND Corporation* 2005.

10. Donahue AK, Tuohy RV: **Lessons we don't learn: A study of the lessons of disasters, why we repeat them, and how we can learn them**. *Homeland Security Affairs* 2006, **2**:1–28.

11. March JG, Sproull LS, Tamuz M: **Learning from samples of one or fewer**. *Organ Sci* 1991, **2**:1–13.

12. Stebbins S, Vukotich CJ: **Preserving lessons learned in disease outbreaks and other emergency responses**. *Journal of Public Health* 2010, **32**:467 –471.

13. Hunter JC, Crawley AW, Petrie M, Yang JE, Aragón TJ: **Local Public Health System Response to the Tsunami Threat in Coastal California following the Tōhoku Earthquake**. *PLoS Currents: Disasters* 2012, **4**:e4f7f57285b804.

14. Savoia E, Agboola F, Biddinger PD: **Use of After Action Reports (AARs) to Promote Organizational and Systems Learning in Emergency Preparedness**. *Int J Environ Res Publ Health* 2012, **9**:2949–2963.

15. Larson RC, Metzger MD, Cahn MF: **Responding to Emergencies: Lessons Learned and the Need for Analysis**. *Interfaces* 2006, **36**:486–501.

16. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group: **Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement**. *PLoS Med* 2009, **6**:e1000097.

17. Mays GP, Scutchfield FD, Bhandari MW, Smith SA: **Understanding the Organization of Public Health Delivery Systems: An Empirical Typology**. *Milbank Q* 2010, **88**:81–111.

18. Mays GP, Halverson PK, Baker EL, Stevens R, Vann JJ: **Availability and Perceived Effectiveness of Public Health Activities in the Nation's Most Populous Communities**. *Am J Public Health* 2004, **94**:1019–1026.

19. Hunter JC, Yang JE, Petrie M, Aragón TJ: **Integrating a framework for conducting public health systems research into statewide operations-based exercises to improve emergency preparedness**. *BMC Public Health* 2012, **12**:680.

20. **CDC Emergency Preparedness & Response Site** [http://emergency.cdc.gov/].

21. U.S. Centers for Disease Control and Prevention (CDC): *Public Health Preparedness Capabilities: National Standards for State and Local Planning*. 2011.

22. Mays GP, Smith SA, Ingram RC, Racster LJ, Lamberth CD, Lovely ES: **Public Health Delivery Systems: Evidence, Uncertainty, and Emerging Research Needs**. *Am J Prev Med* 2009, **36**:256–265.

23. Harris JK, Clements B: **Using social network analysis to understand Missouri's system of public health emergency planners**. *Public Health Rep* 2007, **122**:488–98.

24. Dato V, Wagner MM, Fapohunda A: **How outbreaks of infectious disease are detected: a review of surveillance systems and outbreaks.** *Public Health Rep* 2004, **119**:464–471.

25. National Association of County and City Health Officials (NACCHO): *National Profile of Local Health Departments*. 2010.

26. Meit M, Sellers K, Kronstadt J, Lawhorn N, Brown A, Liss-Levinson R, Pearsol J, Jarris PE: **Governance Typology: A Consensus Classification of State-Local Health Department Relationships**. *J Public Health Man* 2012, **18**:520–528.

27. Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ: **Practical challenges of systems thinking and modeling in public health**. *Am J Public Health* 2006, **96**:538.

28. Leischow SJ: **Systems Thinking and Modeling for Public Health Practice**. *Am J Public Health* 2006, **96**:403–405.

29. Bovaird T: **Emergent Strategic Management and Planning Mechanisms in Complex Adaptive Systems**. *Public Manag Rev* 2008, **10**:319–340.

30. Thompson JD, Zald MN, Scott WR: *Organizations in action: Social science bases of administrative theory*. Transaction Pub; 2003.

31. *Research Priorities in Emergency Preparedness and Response for Public Health Systems: A Letter Report*. National Academy Press; 2008.

32. U.S. Department of Health and Human Services (HHS): *National Health Security Strategy*. 2009.

Tables and Figures

Figures

<u>Figures can be found at the end of Chapter 2</u>

Figure 1 - Literature review flow diagram

This flow chart provides a summary of the steps taken in the systematic literature review, resulting in the 128 articles analyzed within this study.

Figure 2 - Geographic distribution of case reports

This map shows the approximate location of each response community described in the case reports. The color of map markers indicates the type of event, as shown in key. Image developed using Google Map data ©2013 Google, INEGI.

Figure 3 - Two views of organizational involvement in the public health response system

This figure summarizes the contributions of 31 types of organizations to the public health response activities described in the reviewed literature set. The gray bars show the proportion of articles that mention *any involvement* from partners of each organization type. The orange line shows the *extent of involvement*, defined as the proportion of response activities contributed by each organization type, if involved. An asterisk mark is located by the name of the organization types that had significantly different involvement for infectious disease compared to non-infectious disease events, when looking at the measure *any involvement* ($p < 0.05$).

Tables

Table 1 - List of events

Event Category	# of Case Reports	Event detail (# of case reports)
Infectious disease event	101	Salmonellosis (18), Rabies-Human (13), Measles (6), Norovirus (5), Pertussis (4), Shiga toxin-producing *E. coli* (STEC) (4), Cryptosporidiosis (3), Dengue virus (3), Hepatitis C (3), Meningococcal disease (3), Tuberculosis (3), Vaccinia (3), Arboviral diseases (2), Brucellosis (2), Campylobacteriosis (2), Listeriosis (2), Methicillin-resistant *Staphylococcus aureus* (2), Novel influenza A virus infections (2), Adenovirus (1), Ciguatera toxin (1), Clostridium perfringens (1), Cronobacter species (1), Ehrlichiosis/Anaplasmosis (1), Gonorrhea (1), Hantavirus pulmonary syndrome (1), Hepatitis B (1), Histoplasmosis (1)Hookworm (1), Human Immunodeficiency Virus (HIV) (1), Legionellosis (1), Mumps (1), Murine typhus (1), Q fever (1), Scombroid fish intoxication (1), Streptococcal disease, invasive, Group (1), Syphilis (1), Unknown etiologic agent (1), Vibriosis (1), Yersiniosis (1)
Chemical event	16	Lead (2), Atropoine And Scopolamine (Jimsonweed) (1), Bath Salts (1), Chlorine Gas (1), Colchicine (1), Diacetyl (1), Ecstasy (1), Levamisole (1), Marijuana (1), Methyl Bromide (1), Nonpharmaceutical Fentanyl (1), Pyraclostrobin Fungicide (1), Silicone Oil (1), Trichloramine (1), Unknown (1)
Event involving a biological agent (suspected or confirmed)	7	Anthrax (3), Botulism (2), Plague (1), Marburg hemorrhagic fever (1)
Severe weather/Natural disaster	3	Severe winter weather (1), Fire (1), Hurricane (1)
Event with unknown etiology	1	Disease outbreak of unknown cause (1)
Radiation event	0	-
Mass casualty event	0	-
Total	128	

Table 2 - Event characteristics

Event Characteristics	# of case reports	mean	sd	min	median	max	Signif.
Duration of response (in days)	(90)	111	207	2	30	1,461	
Number of individuals contacted to investigated illness or exposure	(124)	869	4,780	0	66	40,000	*
Number of probable or confirmed cases	(126)	101	291	0	9	1,902	
Number of severe cases (number of hospitalizations or deaths)	(127)	19	95	0	1	1,013	
Number of individuals who received prophylaxis	(119)	92	769	0	0	8,270	

*Differences between infectious disease and non-infectious disease events significant at $p < 0.06$.

Table 3 - Public Health Activities: Percent of cases involving each response activity, by event type

Response Activity	Infectious Disease (% of cases, n=108)	Non-Infectious Disease (% of cases, n=20)	Total (% of cases, n=128)	Signif.
Public health surveillance and epidemiologic investigations	100	100	100	
Information sharing	97	95	97	
Public health laboratory testing	92	70	88	*
Non-pharmaceutical interventions	61	70	63	
Environmental or product investigation	50	60	52	
Emergency public information and warning	44	45	44	
Medical countermeasure dispensing	37	0	31	*
Consulting subject matter experts	9	25	12	
Responder safety and health	5	5	5	
Medical material management and distribution	3	0	2	
Mass care and sheltering	0	5	1	
Community recovery	0	5	1	
Emergency operations coordination	1	0	1	
Community preparedness	-	-	-	
Medical surge	-	-	-	
Fatality management	-	-	-	
Volunteer management	-	-	-	

*Difference between infectious disease events and non-infectious disuse events is significant at p<0.05.

Figure 1. Literature Review Flow Diagram

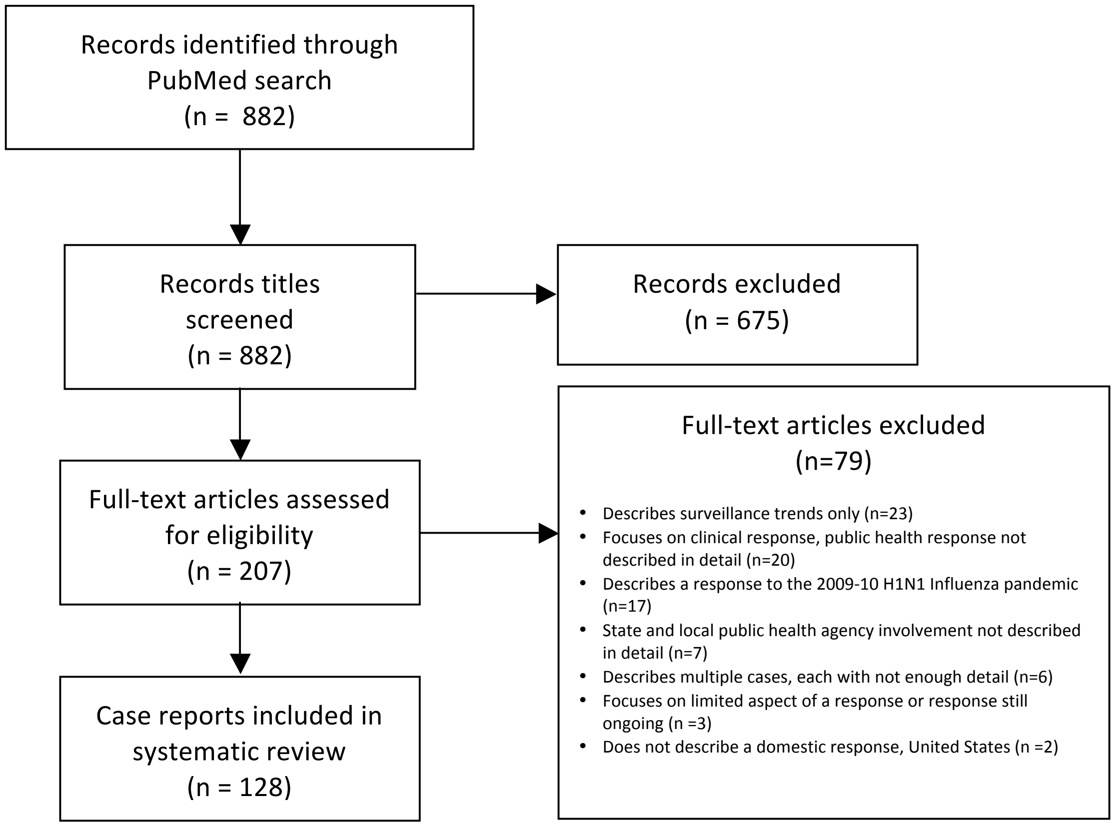


Figure 2. Geographic distribution of cases

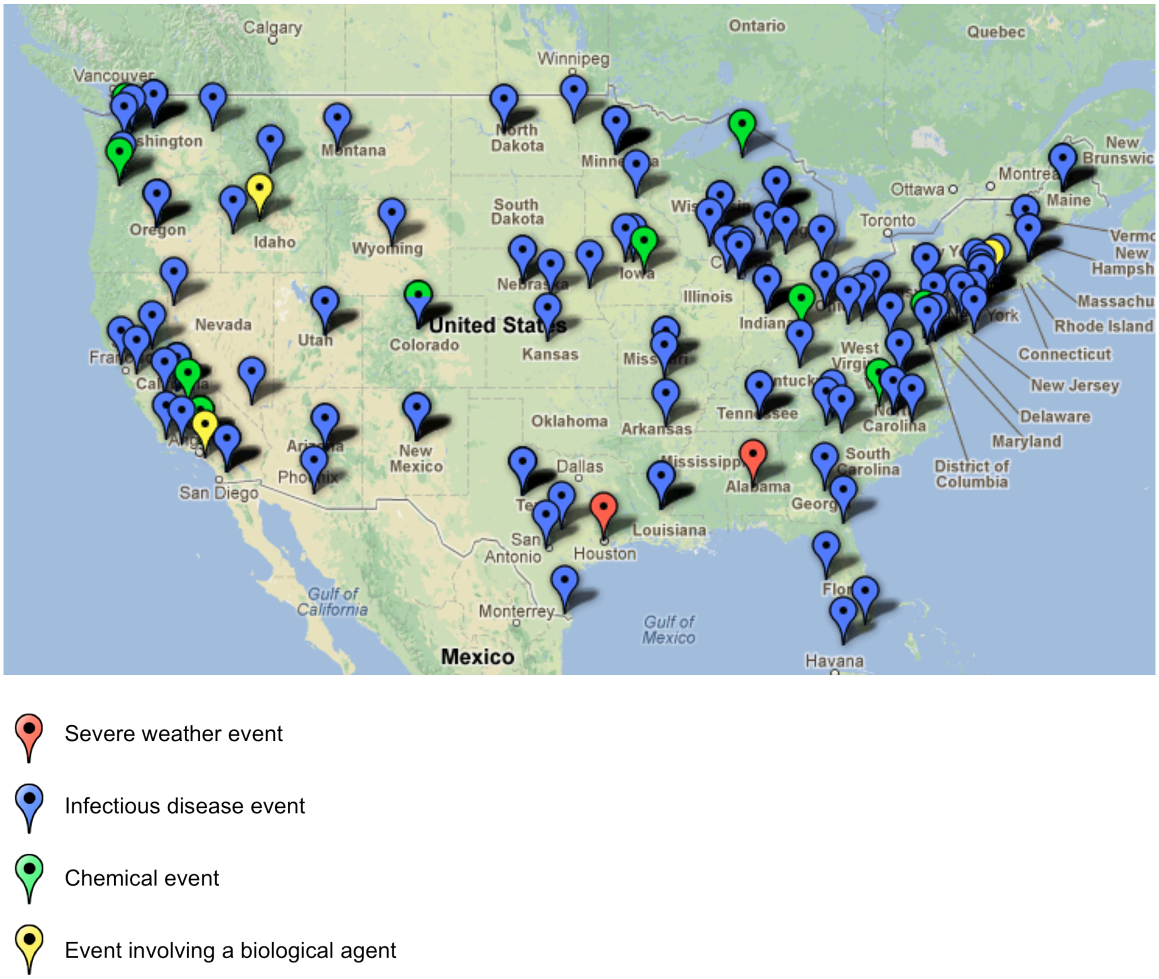
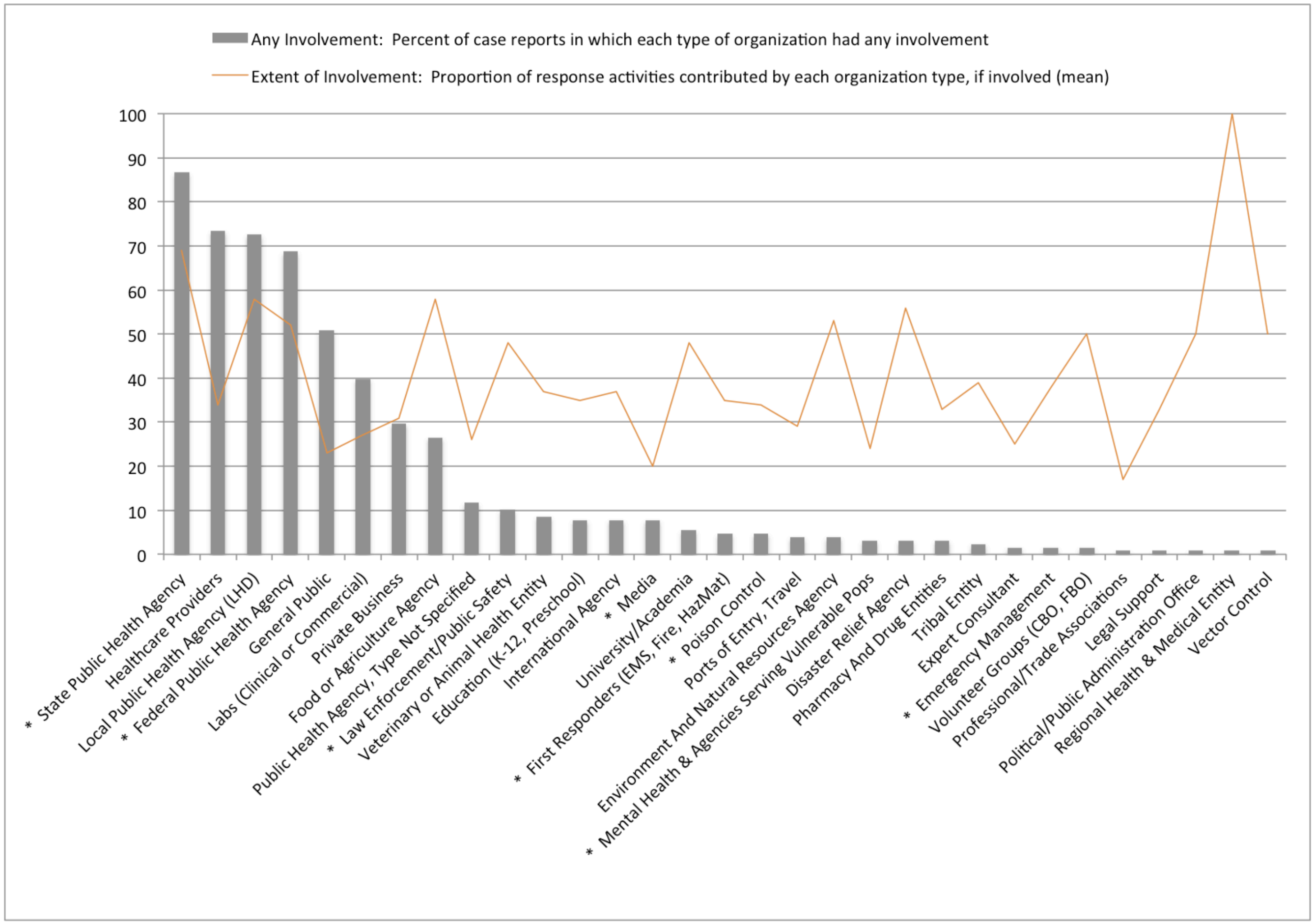


Figure 3. Two views of organizational involvement in the public health response system



CHAPTER 3: PUBLIC HEALTH RESPONSE SYSTEMS IN ACTION: LEARNING FROM HEALTH DEPARTMENTS' EXPERIENCES WITH ACUTE AND EMERGENCY INCIDENTS

Introduction

Described as "medical detectives," public health professionals have a long and storied history of investigating acute, sometimes mysterious, incidents of adverse health events and providing practical recommendations to prevent further illness. Traditionally, field epidemiology has been at the center of this practice, and infectious disease outbreaks have been the typical subject of investigation [1–3]. Over the past decade, however, the expectations for public agency response capabilities and the situations requiring public health action have broadened considerably. In some ways, this broadening was a direct consequence of the anthrax attacks within the United States in 2001 and the resulting concerns about bioterrorism. Expectations have been shaped further by subsequent emergencies, including the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003 and the extraordinary destruction caused by Hurricane Katrina in 2005, which served to solidify a greater appreciation of the role of public health in a variety of acute event scenarios [4, 5]. The now commonly-used terms, "public health emergency" and "all-hazards preparedness," attest to belief that health departments have a responsibility for attending to acute health threats of any type or origin [4, 6].

As expectations have expanded, the need to strengthen public health systems' capacity to respond to any hazard has been at the center of many policy discussions [7]. However, the evidence base to support this priority has lagged behind. There is still little agreement on how to measure, let alone improve public health response performance [8, 9]. A number of challenges have been cited as barriers to research advancement in this field, including the infrequent nature of large-scale public health emergencies, the heterogeneity of emergency events and of public health delivery structures, the challenges with access to incident leadership during real-world emergencies, and the difficulty of identifying a comparison group or constructing a counterfactual of what might have occurred if particular public health interventions had not taken place [8, 10–12]. As a result, researchers have been limited in their use of statistical methods to test hypotheses, reach generalizable conclusions, and isolate factors that are likely to have the greatest impact on response capacity. Additionally, because catastrophic events are, thankfully, infrequent, the majority of the measurement literature in this field has focused on preparedness rather than on response -- on identifying and measuring the inputs to preparedness rather than the variations in response performance. What we do know about public health emergency response is largely derived from simulated emergencies (e.g. exercises or drills), with a primary focus on bioterrorism or pandemic influenza [8]. By relying on an evidence base that draws from a narrow set of threats, we run the risk of overemphasizing the capabilities and resources required for those incidents while neglecting those that may be essential in other scenarios [13].

These limitations pose serious challenges to public heath authorities who seek to evaluate their own response capacity and to direct resources towards evidence-based improvements. They also hinder the ability of stakeholders to keep public health agencies accountable to their mission. In the case of acute events, the level of public health performance can make a difference in the number of lives saved, the illnesses or injuries averted, and the economic and social costs to a community. Consequently, the importance of improving the evidence base concerning performance standards and measures in this field cannot be overstated.

While it is essential that researchers continue to learn from real or simulated catastrophic events and to improve the methods for this type of inquiry, new approaches that might overcome recognized barriers to data collection and shed light on the important performance and policy questions could prove useful. This study is one such attempt. It features two major departures from the current paradigm: (1) concentrating our efforts on characterizing responses to real-world events rather than preparedness efforts to hypothetical scenarios; and (2) comparing response features across incidents rather than identifying lessons learned from single isolated incidents. Guiding this approach is a supposition that, while each event is in some ways unique, the number and type of response activities are finite; therefore, through comparative analysis, we can learn about commonalities in the *response patterns* that could improve predictions and expectations regarding the resources and capabilities required to respond to future acute events. To investigate this theory, we developed a collection of highly structured data on more than 120 real-world acute incidents -- not just disasters -- which together represent the broadest set, to date, of events that have stressed the public health system in the United States. By pooling data across diverse incident contexts and types, we vastly increase the number of opportunities for learning [14–16]. Our hope is that this research can serve as a starting point for the development of evidence-based forecasts that might help shape researchers' and practitioners' expectations for public health behavior during urgent events and identify situations in which a governmental public health response has deviated from these expectations. Such "surprises" can then provide valuable opportunities to improve and update our understanding of response performance by pointing to: (1) a lack of sophistication in our predictive models, (2) adaptive response behaviors, or promising practices, that could be applied in other situations to beneficial effect, or (3) unnecessary variation associated with inefficiencies that may affect the health of a community or the reputation of public health agencies.

Conceptual Framework

Adopting the maxim that "all emergencies are local", and driven by the goal of characterizing the greatest number and diversity of events practicable, we focused this research on describing the public health response systems from the perspective of the local health department. Therefore, we examined three domains through structured interviews with public health authorities involved in response efforts, including: (1) key characteristics of the acute event context, (2) the number and type of public response activities initiated using the CDC Public Health Preparedness (PHEP) capabilities as an organizing framework, and (3) the number and type of organizations contributing to the public health response activities. The domains selected for this investigation were informed by a study of the organization and delivery of local public health services during normal operations by Mays *et al*. (2009), which employed similar measures in the expectation they could reasonably be expected to influence performance and outcomes [17, 18]. We view these response measures as intermediate outcomes between an exposure (i.e. the urgent event) and the final outcomes of interest (e.g. exposures, illnesses, disabilities, deaths) [19].

We expect that the community context, including the availability of local resources and public preferences for the delivery of services, will influence aspects of how the public health system responds to an acute event [17]. However, we posit that the character of the event itself will trigger distinguishable response patterns, regardless of the community context. To test this hypothesis, we compared response measures for traditional infectious disease investigations with less commonly described responses to non-infectious disease events. We also examined response patterns across six CDC-defined hazard categories: infectious disease events, severe weather and natural disasters, bioterrorism events, mass casualty events, chemical emergencies, and radiation emergencies [20]. The resulting profiles provide the first account of the public health response system using quantitative data, which can be used to compare the public health response based on key characteristics and to generate ideas for improving future performance.

Methods

Study design

This research uses a mixed-methods approach. Quantitative and qualitative data on urgent event and response characteristics were collected through structured telephone-based interviews with health department representatives using a retrospective cross-sectional design.

Study population

Selection criteria

One of the primary aims of this investigation is to characterize how public health agencies and their community partners respond to urgent and emergency events at the local level. However, because no comprehensive source of data concerning such events exists, we chose to begin with a sampling frame of local health departments, and to ask recruited representatives to identify eligible events, which would be the subject of the interview. Selection criteria were applied at the level of the health department, the event, and the informant. First, at the level of the public health department, organizations were identified using the 2010 National Profile of Local Health Departments (Profile of LHDs), a national survey completed by more than 80% of the 2,565 local health departments in the United States [21]. We further limited our target population to organizations that serve a population of at least 50,000 individuals. These 963 health departments serve the vast majority of the United States population (89% of the population) and are more likely to have responded to an eligible event, thus improving sampling efficiency [21]. Second, at the level of the event, we asked well-informed health department representatives to select an "urgent event" that their health department had responded to since January 2009. An "urgent event" was defined as one whose scale, timing, or unpredictability overwhelmed or threatened to overwhelm routine capacity [6]. Because the concept of an urgent event is not widely understood or accepted, we also provided a list of possible event types to prompt and guide potential participants' thinking about appropriate events. This list included: infectious disease outbreaks or investigations, environmental contamination, accidental poisoning, severe weather or natural disasters, and other unusual acute public health incidents. Based on our interest in obtaining a wide range of real-world events that are not well characterized in the literature, we excluded events involving simulated emergencies (e.g. exercises or drills) and the 2009 H1N1 influenza pandemic. Third, at the level of the informant, health department representatives had to indicate that they were generally knowledgeable about the overall public health response to the selected event in order to be eligible.

Sampling design

Our initial approach was to employ a sampling strategy that would result in a representative sample of urgent events. However, this approach was not feasible because of the current unavailability of information regarding urgent public health events and the scope of this project. Therefore, our first sampling strategy involved oversampling local health departments that had experienced a recent urgent event (Sample 1, described below). Once this source had been depleted, our second strategy involved randomly sampling eligible health departments in an effort to avoid selection biases associated with our preconceived notions of urgent events (Sample 2, described below). Last, two pilot samples were identified to test the structured interview tool and to assess recruitment rates (Pilot Sample, described below).

Sample 1. The first sampling strategy leveraged prior knowledge of local health departments' recent involvement in urgent event response efforts, thus oversampling eligible organizations and improving the efficiency of sampling. We used data from the Profile of LHDs, in which a sub-set of participating agencies were administered a survey module that asked whether their agency had responded to an "all-hazards emergency" between January 2009 and late 2010. All 171 local health departments that responded affirmatively to this question and that met our other inclusion criteria (i.e. the event was not 2009 H1N1 influenza and the health department served a population of at least 50,000) were included in Sample 1.

Sample 2. Because we were unable to obtain the desired study sample size through the strategy outlined in Sample 1, we employed a second sampling frame to identify an additional 169 LHDs. Again using the 2010 Profile of LHDs, we selected from all participating health departments (serving a population of at least 50,000 individuals) using a population proportional to size probability sampling strategy, in an attempt to ensure that the health departments serving smaller populations were not oversampled. The number of health departments sampled was based on the response rate from Sample 1.

Pilot Samples. The first pilot study included a convenience sample of four LHDs with whom the researchers had a professional connection. The goal of this pilot was to test the data collection instrument with a variety of hazard types and with health department representatives serving different population sizes and governance structures. A second pilot sample of nine health departments was identified to assess whether participation rates might be improved by asking health departments about a specific recent event that affected their community. These organizations were identified based on their involvement in incidents reported through an online disease outbreak alerting system, HealthMap, which aggregates information on incidents from a wide variety of sources [22]. Health departments were selected by applying a random interval to the list of events in the database.

Recruitment

Study recruitment and data collection proceeded in rounds, starting in March 2012 and ending in October 2012. In the initial rounds of recruitment, study invitations were emailed to preparedness coordinators and health officers for sampled LHDs, along with a short description of the survey goals via email from the office of the Principal Investigator of Cal PREPARE, a CDC Preparedness and Emergency Response Research Center at the University of California, Berkeley. Based on the input from our practice-based advisory committee, these two categories of professionals were expected to be the most knowledgeable about the overall response to urgent events. Through this initial recruitment process, we learned that for many health departments, communicable disease control directors or epidemiologists would be the best informed about the overall response to an infectious disease event. As a result, after approximately one-quarter of our sample had been recruited, we shifted our outreach strategy and targeted either (1) the preparedness coordinator, or (2) the communicable disease director or epidemiologist, in an effort to identify a range of infectious and non-infectious disease events. Each round of recruitment lasted six weeks, during which time, individuals were sent the initial email invitation and study description, a reminder postcard by mail, three email reminders, and a telephone or voicemail follow-up. During the recruitment process, individuals were informed that they could forward the invitation to another individual within the health department who might be better positioned to participate, and that multiple individuals could participate in a single interview. Individuals were also given an option to opt-out of recruitment and to provide a reason for non-participation.

Interested individuals were directed to a web-based screening survey, administered through Qualtrics©, which provided instructions on selecting an urgent event that would be the subject of the interview, requested detail on the selected event, and asked whether they were generally knowledgeable about the overall response to this event. Upon submission of this screening survey, individuals were further directed to a web-based appointment scheduling system, ScheduleOnce©, where they could propose a convenient day and time for the interview and provide contact information. Appointment slots were available from 8am-6pm Pacific Time, Monday through Friday, from March through early October 2012, with earlier appointments available upon request. Research staff reviewed screening forms and appointment requests within 24 hours of submission, and either approved the interview time or followed-up with interested individuals, if additional information was required. A confirmation email with interview details (e.g. contact information, length of interview) and a brief interview guide outlining the general interview domains were emailed to confirmed participants. A final email reminder was sent to participants 24 hours prior to the agreed-upon interview time.

As an incentive for participation, all participants were offered a customized report that would summarize their interview and provide a comparison to other participating health department(s) that had experienced a similar event (the comparison group would be anonymous), provided the data were available. Participants were also entered into a raffle to receive monetary prizes, including a top prize equivalent to $500 and five runner-up prizes equivalent to $50, which could be put towards conference registration, UC Berkeley apparel, public health books, or other approved preparedness-related items. Incentives were selected based on input from pilot participants and Cal PREPARE practice-based advisory committee members.

Measurements and Instrument

Instrument

Interviews were conducted by phone using a structured interview tool, which included questions related to the three primary research domains, including: (1) key characteristics of the acute event context, (2) the number and type of public response activities initiated using the CDC Public Health Preparedness (PHEP) capabilities as an organizing framework, and (3) the number and type of organizations contributing to the public health response activities. Each of the measures is described in detail, below. This tool included a combination of structured and open-ended response options. The questions and response options were iteratively developed and refined through testing with over 100 case studies reported in the peer-reviewed literature, revised for use in a telephone-based interview setting, and then further revised after pilot testing with four local health departments. The final interview guide is available in the **Appendix.**

Three interviewers (two primary interviewers and one back-up interviewer) were extensively trained on the intent of each question in the instrument, administration protocols, and response coding. To improve administration consistency and inter-rater reliability, study personnel went through a training process in which they first observed interviews, conducted mock interviews using realistic case material, and then conducted supervised interviews. Another interviewer also recorded data during these training interviews, and all discrepancies in coding and administration were discussed and resolved. Additionally, any questions on interpreting and coding interview responses were discussed throughout the data collection period. After all interviews had been completed, each of the two primary interviewers reviewed the others' completed data collection tools to ensure that coding decisions were consistently applied. Audio recordings of interviews were used for validation, as needed.

Measures

Event characteristics. Each interview was characterized with respect to a number of event features, which were selected with the goal of building a common operational picture that could allow for meaningful comparison across disparate events. Accordingly, each interview was assigned to one of six specific hazard categories, as defined by the CDC Emergency Preparedness and Response website, including: infectious disease outbreaks and incidents, natural disaster or severe weather events, bioterrorism events, mass casualty events, chemical emergency events, or radiation emergency events [20]. An additional "other" category was developed for events that could not be easily categorized using the initial six hazard categories. For the purpose of certain analyses within this investigation, these categories were further collapsed into two groups, (1) infectious disease events, including bioterrorism and infectious disease outbreak events, and (2) non-infectious disease events, comprising the remaining hazard categories. Interviewers asked participants about additional hazard details, as appropriate for each category. For example, for infectious disease events, the disease agent and mode of transmission were recorded, whereas for severe weather or natural disaster events, the type of severe weather event was noted (e.g. hurricane, flooding, severe winter weather). For all interviews, regardless of the hazard category, the following event details were summarized: the duration of the public health response, the number of individuals contacted for investigating illness or exposure, the number of probable or confirmed cases, the number of severe cases (requiring hospitalization or resulting in death), and the number of persons receiving medical countermeasures as part of the public health response. Additionally, for each interview, the geographic location and populations most affected by the event were also recorded.

Public health response activities

We used the CDC Public Health Preparedness Capabilities (PHEP Capabilities) framework and definitions as the basis for characterizing the public health activities carried out in response to the hazard [23]. This framework, developed through a review of legislative and executive directives, expert panel processes, and extensive stakeholder engagement, identifies and defines 15 types of services (grouped in five domains) that public health systems could be expected to deliver during emergencies. We deviated from this framework for the purpose of data collection in three key ways. First, we added four categories that emerged as important public health response activities through previous related work and pilot testing but that were underspecified in the CDC PHEP Capabilities document. These categories included: environmental investigations, evacuation, consulting subject matter experts, and assessing medical and public health response capacity. Second, we eliminated the "preparedness" category, which, during pilot testing, proved to be a confusing concept in the context of a specific response. The third major deviation from the PHEP Capabilities framework was the collection of "other" activities that participants felt were important aspects of the response that had not otherwise been captured in the interview. Without explicitly stating that we were asking about PHEP Capabilities, interviewers listed each of the 19 response activity categories (14 original PHEP Capabilities, four additional categories, and an "other public health response activity" category) and asked participants to indicate if any related activities were initiated in response to their selected event, regardless of which agencies were responsible for these efforts. Additionally, participants were asked to identify which of the response activities were essential, defined as "absolutely necessary to the overall response." A summary score was calculated by summing the total number of public health response activities initiated during an event (between 0 and 17 activities). Based on researchers' interests, additional details were collected on certain response activities, including epidemiologic investigation and surveillance, non-pharmaceutical interventions, and medical countermeasures, results not described in this paper. These questions were developed through a review of the outbreak investigation and field epidemiology literature [2, 24, 25].

Organizational partners

Organizational partners were defined as entities that contributed to any of the aforementioned public health response activities. Therefore, interviewers asked participants to identify the organizations and agencies that contributed to each identified activity category (including their own organization). These entities were recorded using an initial list of 35 pre-identified organization categories, derived from CDC PHEP reporting requirements, the literature describing public health system characteristics, and previous related work by the authors. Any agencies that did not immediately seem to fit into these designated categories were coded as "other" and further described in an open text field. Once the study was completed, both the original and "other" lists were examined to identify natural groupings based on organizational function; these list were reviewed by three experts in preparedness and organizations, and a final list of 41 organization categories was developed [17, 26–28]. After this list was finalized, all interview tools were reviewed again to ensure consistency in organizational coding (A description of the organization types and the categorization process is available in the **Appendix**). Three measures were developed from these data. The first measure, "any involvement", is a dichotomous variable that indicates whether entities from each of the 41 organizational categories contributed to *any* of the 17 public health response activities. The second measure, "extent of involvement", provides a proportion of the public health response activities contributed by each type of organization, when that organization type had any involvement. For each case in which a specific organization type had any involvement, the "extent of involvement" was calculated as the:

$$Extent\ of\ Involvement\ = \frac{Number\ of\ Activities\ Contributed\ by\ Each\ Organization\ Type}{Total\ Number\ of\ Activities\ Performed\ during\ the\ Urgent\ Event}$$

Additionally, a summary measure of the total number of organizational categories mentioned in the interviews was calculated (between 0 and 41 organizations).

Other qualitative measures

After each interview, study personnel were encouraged to write analytic notes or "memos" regarding their general impressions, reflecting on the health departments' primary concerns during the event, unique aspects of the event or response not otherwise captured in the data collection tool, and recurring topics or relationships.

Alternate explanatory variables

Because we expected that the community context and local health department capacity also influences the character of the public health response system, we also conducted an exploratory analysis to assess this relationship [17, 18]. In our conceptual model, these factors have the potential to have a direct effect on the relationship between the exposure (urgent event) and the intermediate outcomes explored in this study. Alternatively, they could act as confounders or effect modifiers. Using data from the 2010 Local Profile of LHDs, we assessed whether the number of response activities and partners varies by the population size served by a health department, health department expenditures, and number of full-time staff [21]. Additionally, we examined whether the response activities and response partners vary based on the nexus of public health authority (at the state or the local level).

Statistical issues

Data recorded on paper-based interview tools were entered electronically into the web-based program, Qualtrics, using double data entry; the data were managed and analyzed using Stata 11 (StataCorp LP, College Station, TX) and merged with organizational data from the Profile of LHDs [21]. Discrepancies identified through double data entry were reviewed and resolved. Distributions of event characteristics, response activities, and response partners were calculated and event profiles were developed to allowing for visual comparisons across the six hazard categories. For event and response measures, the differences between infectious disease and non-infectious disease events were assessed using *t* tests or chi-square tests, as appropriate. Multiple linear regression models were employed to assess the association between organizational factors and response outcomes, controlling for the event type. Information from qualitative memos and open-ended responses was reviewed and organized into themes.

Based on our power analyses, we decided to recruit at least 120 health departments. With this sample size, we expected to have power of 80 percent to detect significant differences of 25 percentage points or more between infectious disease and non-infectious disease events for the response measures of interest.

The protocol for this study was approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley.

Results

Sample demographics

Of the 354 recruited local health departments, respondents from 123 health departments completed an interview, resulting in a 35% response rate. A flow diagram summarizing recruitment, screening, and enrollment is provided in **Figure 1**. The 231 non-responding local health departments included: agencies that were not eligible because they did not have an urgent event that met study criteria (9% of non-respondents), that enrolled in the study but were lost to follow-up during the course of data collection (9%), that declined for reasons provided in **Figure 1** (12%), and that provided no response to study recruitment requests (71%).

Respondents represented health departments in 38 of the 48 US states targeted for recruitment, illustrated as **Figure 2**, with a diversity of community and public health agency characteristics (see **Table 1**). These agencies served populations from 50,000 to several million residents, reported annual expenditures ranging from $1 to more than $500 per capita, and had staffing levels between 10 and more than 1,000 Full-Time Equivalents. Nearly three-quarters of respondents represented health agencies that operate as units decentralized from state health agencies (i.e. locally governed), with responsibility for a geographic jurisdiction defined by county boundaries. Overall, compared to non-respondents, responding agencies were significantly more likely to serve a larger population, have more expenditure per capita, and have more Full Time Equivalent staff (for all values, $p<0.05$).

Informant and interview characteristics

A summary of respondents' functional roles is provided in **Table 1**. The most widely represented positions were those actively recruited, as described in our research protocol, with nearly two-thirds of interviews involving preparedness and response coordinators/directors and almost half involving communicable disease staff (epidemiologists, directors, nurses).

Interviews typically lasted nearly one hour, ranging from 27 minutes to 120 minutes. On average, interviews focusing on infectious disease events were significantly shorter than those focusing on non-infectious disease events ($p<0.05$).

Event Characteristics

Event details

The urgent events included in our study primarily involved infectious disease investigations and severe weather or natural disasters, with each constituting approximately 40 percent of the total. The most commonly reported infectious disease events involved norovirus, *Bordetella pertussis* ("whooping cough"), salmonellosis, and shiga toxin-producing *Escherichia coli* (such as *E. coli* O157:H7). Frequently described natural disasters included severe wind and rain storms, such as hurricanes and tropical storms, severe ice and snow storms, tornados, fires, and floods. Our event set also includes incidents involving chemical exposures, misuse of prescription or illegal drugs, suspected or confirmed exposure to biological agents, radiation, mass casualties, and anticipated mass-gatherings. Additionally, one incident involved a community that received displaced persons after the devastating earthquake in Haiti and saw cases of cholera imported from the impacted region. This interview was characterized as a "complex event" because the incident involved causes that fell into multiple categories. Additional details on the types and frequencies of cases are provided in **Table 2**.

When informants were asked how frequently their health department responds to a similar event on the same scale as the incident they selected for the interview, more than half indicated that this was the only event of its kind in recent history (29% of cases) or that something similar happens once every few years (29%). Other events occurred with a greater frequency, from one to two times per year (28%) to three or more times per year (13%). Every event in the following event categories was considered to occur very infrequently (i.e. less than once per year): mass casualty events, complex events, technological emergencies, and anticipated events.

Other indicators of event severity

Health departments' respondes to events varied widely (see **Table 3**). For example, the shortest response duration was approximately five hours, in the case of a white powder incident, while the longest response lasted multiple years in the case of the Deepwater Horizon oil spill. The number of individuals within the community contacted by health departments and their partners to assess illness or exposure ranged from 0 to 11,000 individuals within the community, resulting in the identification of a mean of 37 confirmed and probable cases, of which a mean of three cases resulted in hospitalization or death. A t-test comparison of the log-transformed variables, *duration of response* and *number of probable or confirmed cases*, revealed that infectious disease events involved significantly more cases ($p<0.05$) than did non-infectious disease events. After excluding events involving biological agents, which tend to be very short in duration, the *duration of response* was also significantly longer in infectious disease events ($p<0.05$).

All severe weather and natural disaster events directly or indirectly resulted in the disruption of community infrastructure or services, including water, sewage, electricity, telecommunications, roads or transportation, as well as the direct delivery of public health and medical services. On average, four types of services were disrupted in these severe weather events. With the exception of technological emergencies, other types of events rarely involved an interruption of community services other than those provided by public health, which were postponed or cancelled due to staff diversions for response activities, something that occurred in nearly a quarter of cases not involving severe weather events.

Populations affected

Overall, the populations considered to have been "disproportionately affected" during urgent events included: persons with chronic medical conditions (23%), senior citizens (20%), or children and adolescents (19%), and low-income individuals (18%). Infectious disease events were significantly more likely to affect occupational populations and children or adolescents ($p<0.05$), whereas non-infectious disease events were more likely to affect the general population at-large as well as vulnerable populations, including those with chronic medical conditions, low-income individuals, and persons with special communication, transportation or supervision needs ($p<0.05$).

Public Health Response Activities

In response to the urgent events included in our study, the range of public health activities initiated by response systems varied considerably (**Figure 3**). Of the 19 activity categories, urgent event response efforts involved between 3 and 18 types of activities, with a mean of ten activities per event. The response activities most commonly initiated were those related to: information sharing and management (100% of events), public health surveillance and epidemiology (98%), emergency public information and warning (89%), non-pharmaceutical interventions (88%), environmental or product investigation (82%), consulting subject matter experts (79%), public health laboratory testing (74%), and emergency operations management (65%).

Activity profiles for each of the six event categories (**Figure 2**) provide a summary of the frequency and distribution of response measures by event type. Non-infectious disease events in our study resulted in a significantly greater number of response activities compared to infectious disease events. This difference was most dramatically illustrated when comparing the activity profile of infectious disease events (Figure 2, top box), in which seven types of activities were initiated in more than half of the events, with severe weather and natural disaster events (Figure 2, second box from top), in which 16 types of activities were carried out in more than half of events. In addition to the number of activities initiated, there were also significant differences in the character of the response activities. As expected, dispensing medical countermeasures, including vaccination and post-exposure prophylaxis, was more likely to occur during infectious disease events ($p<0.05$). In contrast, 11 different types of activities were significantly more common in non-infectious disease events, including: assessment of public health or medical capacity, responder safety and health measures, medical material management and distribution, emergency operations management, volunteer management, mass care and sheltering, fatality management, medical surge, evacuation, and community recovery ($p<0.05$). Further, these differences clustered by activity domain. Whereas most investigation and information-management activities occurred at a similar frequency between infectious and non-infectious disease events, differences were common in the following domains: disease control and prevention, surge management, and community resilience domains. Because severe weather and natural disaster events constituted a majority of the non-infectious disease events, we conducted a sensitivity analysis to assess the robustness of the results. After excluding severe weather and natural disaster events, we found that infectious disease and non-infectious disease events did not differ significantly with respect to the number of response activities, and that the only differences in type of activity consistently present were: dispensing of medical countermeasures, which was still more common in infectious disease events, and emergency operations management, volunteer management, and mass care and sheltering, which remained more common in the non-infectious disease events ($p<0.05$). Additionally, after excluding severe weather and natural disaster events, two new activities appeared to be more common to infectious disease events, including epidemiology/surveillance and laboratory testing ($p<0.05$).

Essential Response Activities

Our measure of *essential response activities,* illustrated as horizontal gray bars in **Figure 3**, provides a summary of activities that were perceived as absolutely necessary to the overall response. For the urgent events in our study, the most common essential activities were: epidemiology and surveillance for ***infectious disease events***; environmental health and mass care and sheltering for ***severe weather events;*** environmental investigations and information management for ***chemical events;*** information management for ***events involving biological agents***; public information and warning for ***radiation events***, and "other" for ***mass casualty events.*** These other activities included patient transport and coordinating family assistance centers. The essential response activities also demonstrate that, despite being frequently initiated across all event contexts, some response measures are more likely to be viewed by responders as "absolutely necessary" for a given event type. For example, while epidemiology and surveillance activities were initiated almost universally during urgent events, they were much more likely to be considered essential for infectious disease events than for other event categories. Similarly, although information sharing and management activities were initiated in all events, they were most likely to be considered essential in those involving bioterrorism and chemical agents.

Participants identified "other" public health activities that were carried out in response to their event but were not captured by our pre-defined activity categories, including those related to: restoring community confidence after an event (e.g. community meetings, counseling individuals), enabling individuals to follow disease prevention and health promotion activities (e.g. obtaining food stamps after food disposal orders, providing financial assistance if ill or infected persons were excluded from work due to risk of disease transmission, providing housing for individuals removed from their homes), contributing to resource coordinating centers to assist affected persons access services and permits from multiple agencies after an event, and assessing legal compliance and breaches of protocols.

Public Health Response System

Overall, public health response systems were comprised of 3 to 25 types of organizations, with a mean of 10 public health system organizations (**Figure 4**). The types of organizations mentioned as participating in more than half of urgent event responses in our study included: local public health agencies, including environmental health (98% of cases); state public health agencies (92%); healthcare providers (78%); members of the general public, including cases, contacts and family members of cases, and other individuals (70%); first responders, including emergency medical services, hazardous materials, and fire (58%); and law enforcement and public safety agencies (56%).

Overall, infectious and non-infectious disease events differed with respect to the numbers and types of public health system partners. The response systems for non-infectious disease events were comprised of significantly greater numbers of organization categories ($p<0.05$). We identified 17 organization types that were significantly more common in non-infectious disease events, including: first responders, law enforcement or public safety agencies, emergency management agencies (local or state), the American Red Cross, agencies serving vulnerable populations (including social welfare and mental health), critical infrastructure, volunteer groups (including medical reserve corps and community- or faith-based organizations), employers or private businesses, persons from political or public administration offices, environmental or natural resources agencies, public information offices, disaster relief agencies, the National Oceanic and Atmospheric Administration, animal or veterinary entities, subsidiary health departments, and “ad-hoc” disaster assistance centers, such as shelters and family assistance centers ($p<0.05$). In contrast, infectious disease response systems were significantly more likely to report involvement by three organization types, including the general public, commercial or clinical laboratories, and federal public health (i.e. CDC). We also conducted a sensitivity analysis to assess the robustness of our findings after excluding severe weather and natural disaster events. We found that the difference in the number of response partners between infectious disease and non-infectious disease events remained after excluding severe weather events ($p<0.05$). However, only half of the previously observed differences in the types of response partners remained, including: general public, first responders, law enforcement, emergency management, American Red Cross, critical infrastructure, and laboratories. ($p<0.05$). Additionally, after excluding severe weather and natural disaster events, two new differences in response partners appeared; involvement of ports of entry entities were more common in non-infectious disease events and involvement of state public health was common in infectious disease events ($p<0.05$).

For each incident, we also calculated the *extent of involvement* or the proportion of initiated response activities to which a participating agency contributed. The vast majority of partner organizations contributed to a very limited proportion of the overall response activities. For example, volunteer organizations were primarily involved in mass care and sheltering or volunteer management activities, whereas the involvement of environmental or agricultural entities was mostly limited to environmental investigation and information sharing. Of forty-one organization types, only five contributed to more than ten percent of response activities, including: local public health agencies, which contributed to a mean of 79 percent of response activities, state public health agencies (38% of response activities), healthcare providers (21%), first responders (14%), emergency management agencies (13%), and law enforcement agencies (11%).

Role of public health in the response system

Informants felt that public health played a “lead role in the overall response” to half of the events in this study, a joint-role in approximately one-third of events, and a supporting role in the remaining events. However, the public health role varied tremendously by type of event, whereby public health was considered to play the lead role in 100% of the radiation and complex emergency cases, 94% of infectious disease cases, 33% of events involving a bioterrorism agent, 30% of chemical events, 9% of severe weather or natural disaster events, and none of the technological emergencies or anticipated events.

Community and Public Health Agency Characteristics

Respondents from health departments in which governmental authority is centralized at the state level or where authority is shared between state and local entities were significantly more likely to choose non-infectious disease events as the subject for the interview, compared to health departments that are decentralized from the state health department ($p<0.05$). The public health system partners more likely to be activated in health departments with centralized or shared systems mirrored those more likely to be involved in responses to non-infectious disease events. However, when the analysis was stratified by infectious and non-infectious disease event categories, the number of response partners and response activities no longer differed by the locus of public health authority. However, we found that during infectious disease events, certain types of entities were more likely to be mentioned by health departments with a centralized or shared structure, including ad-hoc disaster assistance centers and subsidiary local health departments, whereas local health departments were significantly more likely to be mentioned by representatives from decentralized health departments. No significant differences in the types of organizational response partners were identified for non-infectious disease events. With respect to response activities, decentralized health departments were more likely to report conducting laboratory activities during infectious disease events and environmental or product investigation during non-infectious disease events.

To assess the independent effect of agency characteristics on the response structure and function, multiple linear regression models were used to assess the relationship between the community and agency measures (predictor variables: size of the population served by a LHD, number of FTEs, and annual per capita expenditures) and response measures (outcome variables: number of organizations involved in the public health system response, number of response activities initiated during the response) controlling for the type of event (infectious disease versus non-infectious disease). Each of the six models included a single predictor and outcome variable, controlling for the type of event. We use the natural logarithm of each predictor variable and employed robust standard errors in the statistical models to minimize the effects of outliers and heteroskedasticity. Controlling for the type of event, only the models including the number of full time staff were significantly and correlated with the number of response activities ($F=37.88$, $p=0.005$) and the number of partners ($F=57.88$, 0.016). This correlation indicates an independent and inverse correlation between the number of public health department staff and the number of organization and activities activated during an event.

Response reporting and dissemination

Eighty percent of respondents indicated that their health department developed a report describing their response efforts. Approximately two-thirds of these health departments developed after-action reports, which were disseminated internally (66% of AARs), to contributing agencies (46%), or to the state health department (37%). In only 11 instances was a summary report widely disseminated, either in the peer-reviewed literature (4% of all cases), in the *Morbidity and Mortality Weekly Report* (3%), or through the Department of Homeland Security Lessons Learned and Information Sharing web portal (LLIS, 2%)

Discussion

Our study provides a rare inside look at the response operations of health departments and their community partners during a remarkable range of acute incidents. Public health representatives described their experiences responding to more than 120 incidents involving unusual clusters of illness, unexpected exposures to hazardous substances, or the sudden loss of infrastructure that we rely on for healthy communities. Regardless of the character of the event or the populations affected, nearly every informant portrayed a situation that compelled his or her public heath agency to work with a network of other organizations to take rapid action in an effort to mitigate, control, or prevent expected adverse heath consequences, often in highly stressful and politically charged environments with demanding expectations for performance. Our results reveal that these public health systems are responsive and adaptive to the character of the threat, resulting in differential activation of functions and partners based on the type of incident.

Our description of the public health response system, the first of its kind, offers practice-based evidence that may help shape expectations about the structural and functional characteristics of the public health response sytem. Our findings align with the National Health Security objective, "ensuring that all systems that support national health security are based on the best available science, evaluation, and quality improvement methods." [29]. The informants in this study described a system that differs dramatically from the one depicted in the 2008 Institute of Medicine (IOM) report, *Research Priorities in Emergency Preparedness and Response for Public Health Systems* [30]. The IOM report designated seven "key actors", which are visually displayed as inter-connected ovals in a diagram of the system, along with "unshaded ovals that represent the necessary overlap between the key actors as well as the many less obvious actors that play a significant role in integrating the public health preparedness system." A first clear difference between the public health preparedness system described in the IOM report and the one presented in our study concerns the number and diversity of organizations involved. The 41 types of entities identified by our informants, many of which have also been referred to in the published preparedness literature, shed light on the character and contribution of these "less obvious actors" [17, 26–28, 31, 32]. Additionally, our system profiles provide an indication of the frequency and circumstances with which these organizations might become involved in public health response activities. Furthermore, we found that some entities are likely to take part in a public health response of any nature, including public health agencies, healthcare providers, and members of the general public, whereas many other organizations are either infrequently involved in public health responses or typically have a role only under specific event circumstances. The American Red Cross provides a good example of an organization that was almost universally active in our severe weather and mass casualty events and sometimes involved in response to chemical or drug threats, but rarely took part in infectious disease or bioterrorism events. For public health agencies that infrequently experience certain types of events, and therefore have few opportunities to interact with particular partners, our findings may provide a new impetus for building or strengthening ties with related organizations. For all public health agencies, tailored outreach efforts should be informed by recognizing that the partner agencies described in our study, with few exceptions, lent their expertise or resources in a very limited proportion of the overall public health responses. As a result, only a fraction of response efforts will be salient to those organizations. Second, while the IOM report presented a system that appears static, our study found a system in which the numbers and types of response organizations, as well as the role of public health agencies, varied significantly, depending on the type of threat the health department faced. The public health response to severe weather events, for example, involved a much larger and more diverse set of partners than the responses to infectious disease events. However, public health departments were ten times more likely to serve in a lead role for infectious disease events compared to events involving severe weather. This lead role, and the responsibilities that come with it, could have great implications for the skills and training necessary for public health staff, particularly those in leadership positions. We also found that characteristics of the health department, most notably the number of full-time staff, influence the number of response activities and partners. Those health departments with a greater number of personnel initiated significantly fewer activities and engaged fewer organizational partners, regardless of the type of event. Previous research has shown that health departments have varying capacity to deliver routine public health services internally and that there are measurable differences in the extent to which agencies rely on external organizations for these functions [17]. It is, therefore, not surprising to learn that characteristics of the health department may also influence aspects of the response. To explain this finding, we hypothesize that organizations with higher staffing levels have greater internal capacity to carry out public health response measures and therefore rely on fewer organizations during a response. It is not clear why the other organizational characteristics that we examined (e.g. annual per capita expenditures, population size served by the health department) were not independently associated with the response outcomes, as we they also seem to be indicators of health department capacity.

From a research perspective, our findings could be of interest to a number of disciplines, particularly complexity science. Public health systems have previously been described as "complex adaptive systems"; however, this classification has yet to be examined empirically, as it has in disaster response more generally [33, 34]. As defined by Bovaird (2008), "complex adaptive systems" are characterized by a self-organizing network of organizations, comprised of a number of diverse organizations, in which power and control are highly dispersed, and where organizations are highly interconnected [35]. Using aspects of this definition, our findings suggest that, on the whole, severe weather events frequently elicit responses by systems with a *greater number* and *more diverse set of organizations*, and, therefore, may be considered more complex than non-infectious disease events. The severe weather response systems are more likely to include individuals from organizational cultures quite different from that of public health, including individuals with dissimilar training, expectations regarding authority and hierarchy, and beliefs about decision-making and how conflicts should be resolved. One implication of these findings is that responders in events involving particularly complex systems may be expected to experience predictable challenges to effective communication and coordination [36]. Public health preparedness could, therefore, benefit from being studied by researchers who study other complex organizational systems and who may be able to help build expectations around the character of these challenges, their consequences, and strategies for avoiding critical failure points during urgent events.

We used a capabilities-based approach as an organizing framework for conceptualizing public health response activities. This planning model, based on an assumption that preparedness can be achieved by directing resources towards building, testing, and improving defined priority areas, is at the core of the CDC "preparedness capabilities" that were used to characterize the response activities described by our informants. Consequently, our results complement the PHEP Capabilities by highlighting the circumstances in which related activities or functions might have particular relevance in practice. Not surprisingly, our study finds that certain types of events were much more likely to elicit response activities related to particular capabilities, and that the frequencies with which capability-related activities were performed did not necessarily equate with how "essential" that capability was to the overall event. For example, the epidemiology and surveillance capability was almost universally activated. However, it was more likely to be considered "essential" for certain types of events, particularly infectious disease events. Linking our results to the CDC preparedness capabilities framework may be of particular value to preparedness planners, for example, by guiding the selection of exercise scenarios that would be most likely to trigger activities related to the capabilities they seek to assess or improve. In addition to the original preparedness capabilities, we also asked participants about four additional categories of activities that were identified through our previous research [unpublished] and pilot testing as (1) important and (2) of a different character than the PHEP Capabilities. These activities included: environmental or product investigation, consulting subject matter experts, assessing public health or medical capacity, and evacuation. We believe that under-specification of important response functions can have serious consequences, particularly in an era of limited resources, where health departments are able to direct resources to only a limited number of preparedness improvements. Therefore, we believe that these activities may have a place in future discussions about what it means for a community to be prepared. Because informants mentioned these activities with such frequency, environmental and product investigations stand out as a particularly good subject for further discussion and consideration, perhaps even as a candidate for inclusion in a future iteration of PHEP Capabilities. Currently, environmental investigations are folded into the "epidemiology and surveillance" capability; however, the resources, staffing, and partners required for these activities are quite distinct from those required for epidemiology and surveillance. Furthermore, our study found that environmental investigations are frequently initiated across all urgent events and that this activity is considered to be "essential" in more than one-third of infectious disease, chemical, and severe weather incidents. Additionally, our informants mentioned a variety of "other" public health activities that were carried out in response to their event, but that they felt were distinct from the PHEP Capabilities, and may also merit further attention. These include activities related to: restoring community confidence after an event (e.g. community meetings, counseling individuals), enabling individuals to follow disease prevention and health promotion activities (e.g. obtaining food stamps after food disposal orders, providing financial assistance if ill or infected persons were excluded from work due to risk of disease transmission, providing housing for individuals removed from their homes), contributing resource coordinating centers to help affected persons access services and permits from multiple agencies after an event, and assessing legal compliance and breaches of protocols.

One of the ultimate goals of this research is to develop a typology that classifies events based on important sources of variation in the structural and functional aspects of the public health response system. By defining a few meaningful configurations common to public health response efforts, we hope to help public health managers develop and evaluate their preparedness programs. For example, while far from comprehensive or validated, our data might suggest three models of response. In the first model of response, most typical of infectious disease events, public health agencies serve in the lead role to the overall response; response activities and partners are more limited in number and type; the number of cases define event severity; and the epidemiology and surveillance function is considered most essential to the response. In the second model of response, most typical of severe weather and natural disasters, public health agencies serve in a joint or supporting role to the overall response; response activities and partners are more numerous and diverse; disruption to community infrastructure defines event severity; and environmental health and mass sheltering and care activities are considered most essential to the response. In the last model of response, typical of events involving chemical exposure or biological agents, public health agencies serve in a joint or supporting role to the overall response; response activities are moderate in number; response systems involve atypical partners; number of persons exposed defines event severity; and information and incident management activities are considered most essential to the response. Models such as these could have implications for planning and exercising with partner agencies, particularly with respect to setting expectations and developing a mutual understanding about the roles and responsibilities of public health agencies in various situations, an issue that has repeatedly been recognized as an area for improvement [8, 32].

Strengths

Our study benefits from three major strengths, including active case finding, a broad definition of urgent events, and the use of interviews as a data collection method. Our recruitment methods were costly and took considerable effort. However, as a result, we were able to gain access to a number and diversity of urgent event cases that would not have otherwise been available. In fact, fewer than ten percent of the cases included in this investigation were published in the peer-reviewed literature or other professional information-sharing web portals, confirming our presupposition that the publicly available literature describes a very limited proportion of events experienced by LHDs. It may be worth noting that when we initially proposed this project, several practitioners and researchers advised the use of the Department of Homeland Security's Lesson Learned and Information Sharing (LLIS) web portal, which they believed contained a fairly comprehensive set of response summaries. Only two percent of our cases indicated that resulted in the submission of a summary report to this database. Another strength of this study is the adoption of a broad definition of urgent events, thereby greatly expanding the available case material on public health responses. By pooling data across cases with different contexts, we had a sufficient sample size to examine patterns, highlight commonalities and differences across events with different contexts, and generate hypotheses for future study. Third, because this is a fairly new field of research, the use of interviews for data collection was invaluable, as this method provided respondents the opportunity to ask for clarification on questions and for interviewers to ask follow-up questions and to hear how health department representatives describe their response. These qualitative data, while not highlighted in our findings, greatly influenced the insights we drew from the data. This study was also strengthened by the availability of organizational data, provided by 2010 Profile of LHDs, which provided a sampling frame of local health departments, allowing us to better understand the representativeness of our sample and interpret our findings, and affording us the opportunity to examine how characteristics of a health department influence our outcomes of interest [21]. Finally, our approach also draws strength from the application of a systems-based and functions-based approach, both seen as essential features of high-quality research in this field [8]. By using the CDC Public Health Preparedness capabilities as a framework for conceptualizing public health activities, we hope to be able to contribute to the scientific literature in a way that is standardized, and thus allows for comparison with future research.

Limitations and Next Steps

While our results describe the responses to a wide range of incidents, our findings do not draw from a sample that is representative of health departments or urgent public health incidents across the United States. Representativeness was not a cornerstone of our sampling goal; however, in order to appropriately interpret the findings of this study, we believe that it is important to recognize the ways in which our findings are not representative. First, while we were able to achieve the desired number of cases for comparison, we had a fairly low overall response rate (35%). Based on the reasons for not participating provided by a subset of our non-respondents, a significant proportion of health departments in this group may not have experienced an incident that met study criteria. Therefore, we believe that the true response rate of *eligible* LHDs was considerably higher. Nonetheless, we recognize that respondents systematically differed from non-respondents: they were significantly more likely to serve a larger population, have higher public health expenditures per capita, and have more full-time staff. Non-respondent health departments' capacity or inclination to participate may be related to a specific response profile that is underrepresented in our results. Second, we allowed respondents to select a single event, which is one of many from which they could have potentially chosen. We do not claim to know anything about the events that were not selected; therefore, it is not possible to know how representative our set of events really is. We do know that the distribution of event types in our sample is similar to that found in other research. However, information is at the event type level (e.g. severe weather), and this may mask important details regarding the frequency of specific events that would be important for a more complete understanding of representativeness (e.g. a health department may have noted that they experienced an infectious disease event and a chemical event, when in reality they experienced ten infectious disease outbreaks and one chemical event) [21]. Furthermore, certain types of events occur more frequently in our dataset, such as norovirus outbreaks and hurricanes. As a result, each event profile is more greatly influenced by these more frequent events. Last, health departments that served a population of fewer than 50,000 individuals were excluded from our sampling strategy. The response system attributes of these health departments, which often have very limited staffing, warrant additional study.

A second limitation of this investigation is that our results tell us only whether certain activities were initiated and partners were involved in a response. We did not attempt to characterize the quality or appropriateness of those partners or activities, given the context of a particular event. Additionally, we do not provide information on the organizational, inter-personal, leadership, training, and historical factors that likely influenced whether responding agencies considered response measures to be appropriate and actionable. We stripped cases of this context, not because we believe context does not matter. Far from it. We believe that a careful examination of these contextual factors, using the right case material, could be exactly what is needed to elucidate mechanisms for improving the delivery of public health services during acute events. However, we think it is equally valuable, particularly at this stage, to describe the landscape of urgent events in a way that might help other researchers ask better and more informed questions. Furthermore, in the absence of validated performance measures, we were unable to link these data to meaningful outcomes.

As an extension of this work, we recommend that future studies examine the types of events that were less commonly reported in our sample, including mass casualty and chemical events, and to build on the profiles that we have developed to-date. If these profiles prove to be useful to practitioners or researchers, it may be valuable to investigate mechanisms for ongoing data collection and dissemination. To further explore this idea, we have developed a collaboration with a research group that seeks to test the feasibility and utility of creating a "Critical Incident Registry," similar to one used by the airline industry as a tool for learning from crashes and near-misses [Stoto *et al,* unpublished]. Last, with little previous research to rely on, we took a broad and inductive approach to learning about public health response systems. We hope that the findings from this research will serve as a catalyst for future research that help us to better understand, measure, and improve public response systems.

Conclusion

In this study, we collect highly structured data on more than 120 real-world acute public health incidents. This represents the broadest set, to date, of events that have stressed the public health system in the United States. As a result, we are able to make comparisons across events and to identify functional and structural response patterns that could have relevance to public health practitioners and researchers.

Tables and Figures

Figures

<u>Figures can be found at the end of Chapter 3</u>

Figure 1. Recruitment Flow Diagram

This flow diagram summarizes the sampling and recruitment steps that resulted in the study population of 123 local health departments. Reasons for non-participation are provided, where possible.

Figure 2. Geographic distribution of cases

This map shows the distribution of participating agencies across the United States. States with greater number of participating local health departments (LHDs) are shaded darker red. States with the greatest number of participating health departments included California (12 LHDs), Ohio (8 LHDs), North Carolina (8 LHDs), Texas (7 LHDs), Florida (7 LHDs), and New Jerseyy (7 LHDs). Image developed using Google Map data ©2013 Google, INEGI.

Figure 3. Response activity profiles, by event type

This figure shows the profile of response activities for each of six different types of events, displayed as separate bar charts. For a given event type, the blue vertical bars show the proportion of cases that involved each of the 19 defined response activities. The horizontal gray bars provide the percent of cases for which that activity was perceived to be "essential." For example, within infectious disease events (top box), 100% of cases involved epidemiology and surveillance (Activity A), and in 82% of cases this activity was felt to be essential. The activities are ordered by five functional domains: investigation, disease control and prevention, information and incident management, surge management, and community resilience.

Figure 4. Public health response system profiles, by event type

This figure shows the public health response system profile for each of six different types of events, displayed as separate bar charts. For a given event type, the green vertical bars show the proportion of cases that involved each of the 41 defined response partners. For example, within infectious disease events (top box), 98% of cases involved local public health agencies (Organization Type A). The types of organizations are ordered based on the overall frequency with which they were mentioned in all 123 cases, most frequent to least frequent, from left to right. A gray bar, at the 50% marker, is included in each bar chart to highlight those organizations involved in more than half of cases.

Tables

Table 1. Participating Local Health Departments and Respondent's Role

This table provides a descriptive summary of respondents including characteristics of the public health agency and agency representatives.

Continuous Variables	mean	median	min	max	Signif
Population size (in thousands), n=123	542	297	51	>2,000	*
Expenditures per capita, n=111	78	43	<10	>200	*
Number of Full Time Equivalent staff (FTE), n=113	333	122	10	>1000	*
Categorical Variables	n	% of Cases			
Governing authority					
Centralized authority at the state	18	15			
Decentralized, authority at the local level	84	69			
Shared or mixed	19	16			
Geographic area served by agency					
City	14	12			
City-county	2	2			
County	85	70			
Multi-city	3	2			
Multi-county	17	14			
Types of Services directly provided by agency					
Comprehensive primary care services	20	17			
Any environmental health services	105	85			
Position or title of respondent(s)[1]					NA
Preparedness and Response	78	63			
CD Staff/Epidemiologist	48	39			
Environmental Health	12	10			
Health Director/Deputy	13	11			
Health Officer/Deputy	7	6			
Other	25	20			

[1] Respondents could identify more than one position or title

Table 2. List of events

This table summarizes the total number of cases within each event category and provides the number of cases for each sub-category event (e.g. number of urgent event cases involving the disease pertussis).

Event Category	# of Case Reports	Event detail (# of case reports)
Infectious disease event	51	Norovirus (9), Pertussis (7), Salmonellosis (6), Shiga toxin-producing *Escherichia coli* (STEC) (4), Tuberculosis (3), Hepatitis A (2), Measles (2), Meningococcal disease (2), Mumps (2), *Bacillus cereus* (1), Botulism (1), Campylobacteriosis and Guillian Barre Syndrome (1), Coliform bacteria (1), Cryptosporidiosis (1), Cyclosporiasis (1), Hantavirus pulmonary syndrome (1), Legionellosis (1), Lyme disease (1), Novel influenza A virus infections (1), Rabies-Animal (1), Shigellosis (1), Unknown Etiologic Agent (1), Varicella (Chicken pox) (1)
Severe weather/Natural disaster	45	Hurricane/Tropical Storm (16), Severe winter weather (7), Tornado (7), Flooding (5), Fire (5), Severe rain or wind storm/derecho (5)
Chemical or drug event	10	Bath Salts/White Rush (1), Hydrogen Sulfide, Natural Gas, Mercaptans (1), Blueberry Spice (Designer Drug) (1), Diesel Fuel And Lubricating Oil (1), Hydrogen Sulfide/Methane Gas (1), Pulverized Limestone (1), Crude Oil, Tarballs (1), Isocyanate (1), Liquid Mercury (1), Lead, Arsenic (1)
Radiation event	4	Iodine-131, Cesium-134, Cesium-137 (3), Strontium-82 And Strontium-85 (1)
Mass casualty event	2	Explosion (1), Plane crash (1)
Technological emergency	2	Mechanical failure at water treatment plant (1), Transformer fire (1)
Anticipated event	2	Planned mass gathering (1), Displaced persons from natural disaster/severe weather (1)
Complex event	1	Displaced persons from natural disaster/severe weather & infectious disease outbreak (cholera) (1)
Total	123	

Table 3. Event Characteristics

This table summarizes key event characteristics, including: duration of response time, number of individuals contacted to investigate illness or injury, number of probable or confirmed cases, number of severe cases, and number of individuals who received prophylaxis.

Event Characteristics	# of case reports	mean	sd	min	median	max	Signif.
Duration of response (in days)	(123)	64	125	0.2	18	854	**
Number of individuals contacted to investigated illness or exposure	(96)	756	2,111	0	80	11,000	
Number of probable or confirmed cases	(90)	37	82	0	7	565	*
Number of severe cases (number of hospitalizations or deaths)	(106)	3	7	0	0	51	
Number of individuals who received prophylaxis	(27)	1,253	2,376	0	161	10,240	

*Differences between infectious disease and non-infectious disease events significant at $p < 0.05$
**Differences between infectious disease (excluding events involving a bioterrorism agent) and non-infectious disease events significant at $p < 0.05$

References

1. Roueché B: *The medical detectives*. Washington Square Press; 1982.

2. Gregg MB: *Field epidemiology*. Oxford University Press US; 2002.

3. Thacker SB, Buffington J: **Applied epidemiology for the 21st Century**. *Int J Epidemiol* 2001, **30**:320 –325.

4. U.S. Senate: *Pandemic and All-Hazards Preparedness Act. Report [to accompany S. 3678]*. 2006:109–319.

5. Hodge JG, Gostin LO, Vernick JS: **The Pandemic and All-Hazards Preparedness Act**. *JAMA-J Am Med Assoc* 2007, **297**:1708 –1711.

6. Nelson C, Lurie N, Wasserman J, Zakowski S: **Conceptualizing and Defining Public Health Emergency Preparedness**. *Am J Public Health* 2007, **97**:S9–S11.

7. Centers for Disease Control and Prevention: *Public Law 109-417, § 101 et seq. Pandemic and All-Hazards Preparedness Act (PAHPA)*. 2006.

8. Acosta J, Nelson C, Beckjord E, Shelton S, Murphy E, Leuschner KJ, Wasserman J: *A National Agenda for Public Health Systems Research on Emergency Preparedness*. RAND Corporation; 2009.

9. Asch SM, Stoto M, Mendes M, Valdez RB, Gallagher ME, Halverson P, Lurie N: **A review of instruments assessing public health preparedness.** *Public Health Rep* 2005, **120**:532–542.

10. Nelson C, Lurie N, Wasserman J: **Assessing Public Health Emergency Preparedness: Concepts, Tools, and Challenges**. *RAND Corporation* 2007.

11. Lurie N, Wasserman J, Nelson CD: **Public health preparedness: Evolution or revolution?** *Health Affair* 2006, **25**:935.

12. National Biodefense Science Board: *Call to Action: Include Scientific Investigations as an Integral Component of Disaster Planning and Response*. 2011.

13. Nelson CD, Willis HH, Chan EW, Shelton SR, Parker AM: **Federal Initiative Increases Community Preparedness For Public Health Emergencies**. *Health Affair* 2010, **29**:2286 –2293.

14. Savoia E, Agboola F, Biddinger PD: **Use of After Action Reports (AARs) to Promote Organizational and Systems Learning in Emergency Preparedness**. *Int J Environ Res Publ Health* 2012, **9**:2949–2963.

15. Donahue AK, Tuohy RV: **Lessons we don't learn: A study of the lessons of disasters, why we repeat them, and how we can learn them**. *Homeland Security Affairs* 2006, **2**:1–28.

16. Larson RC, Metzger MD, Cahn MF: **Responding to Emergencies: Lessons Learned and the Need for Analysis**. *Interfaces* 2006, **36**:486–501.

17. Mays GP, Scutchfield FD, Bhandari MW, Smith SA: **Understanding the Organization of Public Health Delivery Systems: An Empirical Typology**. *Milbank Q* 2010, **88**:81–111.

18. Mays GP, Halverson PK, Baker EL, Stevens R, Vann JJ: **Availability and Perceived Effectiveness of Public Health Activities in the Nation's Most Populous Communities**. *Am J Public Health* 2004, **94**:1019–1026.

19. Hunter JC, Yang JE, Petrie M, Aragón TJ: **Integrating a framework for conducting public health systems research into statewide operations-based exercises to improve emergency preparedness**. *BMC Public Health* 2012, **12**:680.

20. **CDC Emergency Preparedness & Response Site** [http://emergency.cdc.gov/].

21. National Association of County and City Health Officials (NACCHO): *National Profile of Local Health Departments*. 2010.

22. **HealthMap** [http://healthmap.org/en/].

23. U.S. Centers for Disease Control and Prevention (CDC): *Public Health Preparedness Capabilities: National Standards for State and Local Planning*. 2011.

24. Aragon T, Enanoria W, Reingold A: *Outbreak Investigation: Quick Reference Guide*. CIDER; 2009.

25. Reingold AL: **Outbreak investigations–a perspective.** *Emerging Infectious Diseases* 1998, **4**:21.

26. Mays GP, Smith SA, Ingram RC, Racster LJ, Lamberth CD, Lovely ES: **Public Health Delivery Systems: Evidence, Uncertainty, and Emerging Research Needs**. *Am J Prev Med* 2009, **36**:256–265.

27. Harris JK, Clements B: **Using social network analysis to understand Missouri's system of public health emergency planners**. *Public Health Rep* 2007, **122**:488–98.

28. Dato V, Wagner MM, Fapohunda A: **How outbreaks of infectious disease are detected: a review of surveillance systems and outbreaks.** *Public Health Rep* 2004, **119**:464–471.

29. U.S. Department of Health and Human Services (HHS): *National Health Security Strategy*. 2009.

30. *Research Priorities in Emergency Preparedness and Response for Public Health Systems: A Letter Report*. National Academy Press; 2008.

31. Biddinger PD, Cadigan RO, Auerbach BS, Burstein JL, Savoia E, Stoto MA, Koh HK: **On Linkages: Using Exercises to Identify Systems-Level Preparedness Challenges**. *Public Health Rep* 2008, **123**:96–101.

32. Stoto MA, Dausey DJ, Davis LM, Leuschner K, Lurie N, Myers S, Olmsted S, Ricci K, Ridgely MS, Sloss EM, others: **Learning from experience: the public health response to West Nile virus, SARS, monkeypox, and hepatitis A outbreaks in the United States**. *RAND Corporation* 2005.

33. Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ: **Practical challenges of systems thinking and modeling in public health**. *Am J Public Health* 2006, **96**:538.

34. Leischow SJ: **Systems Thinking and Modeling for Public Health Practice**. *Am J Public Health* 2006, **96**:403–405.

35. Bovaird T: **Emergent Strategic Management and Planning Mechanisms in Complex Adaptive Systems**. *Public Manag Rev* 2008, **10**:319–340.

36. Thompson JD, Zald MN, Scott WR: *Organizations in action: Social science bases of administrative theory*. Transaction Pub; 2003.

Figure 1. Recruitment Flow Diagram

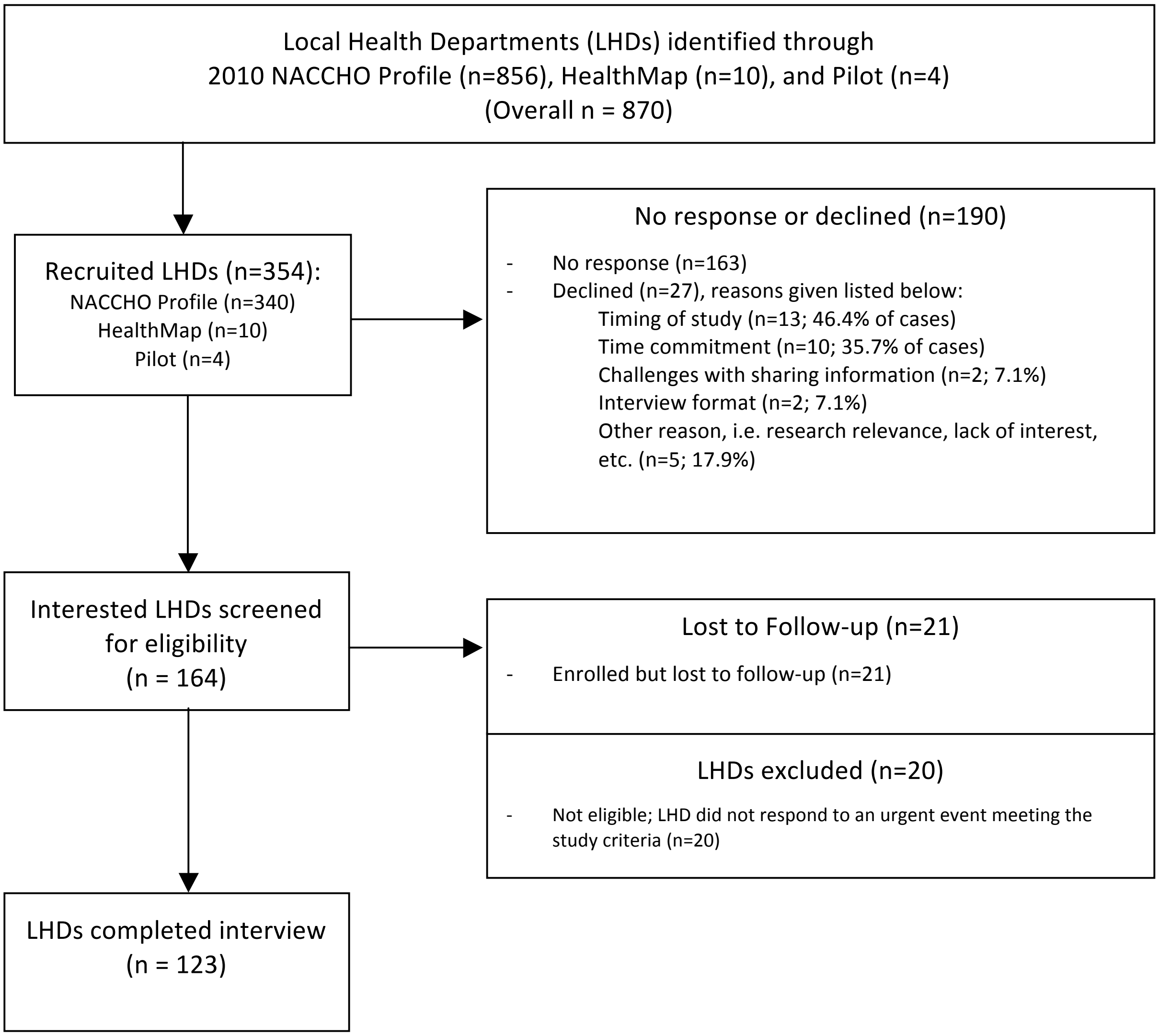


Figure 2. Distribution of cases

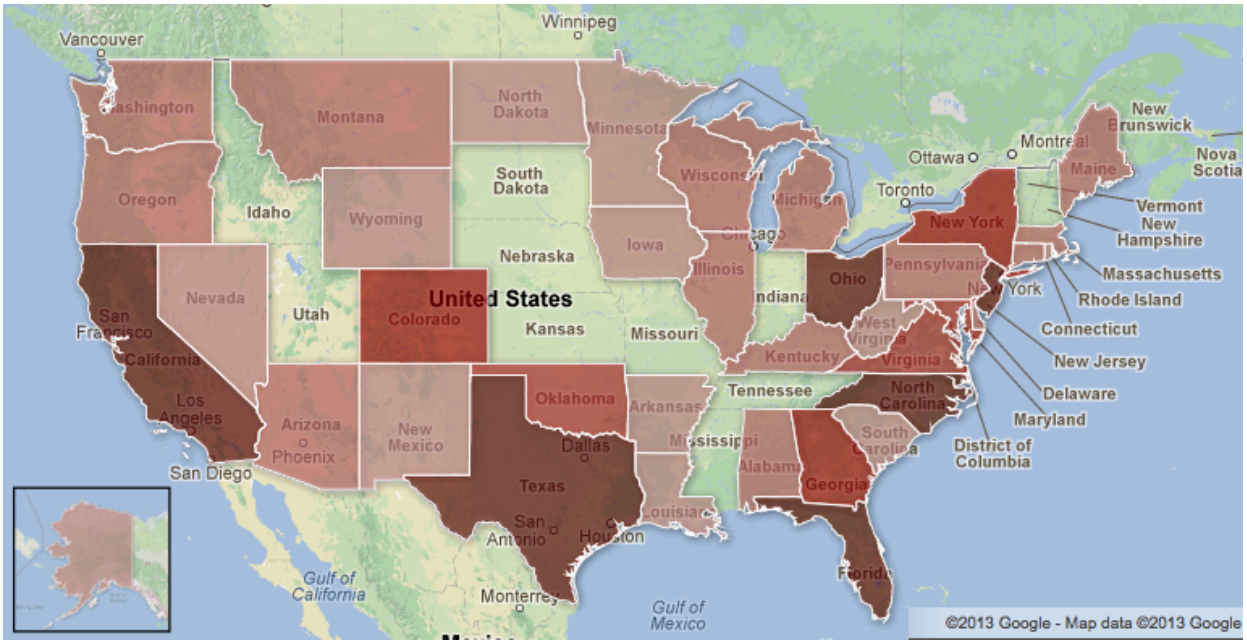
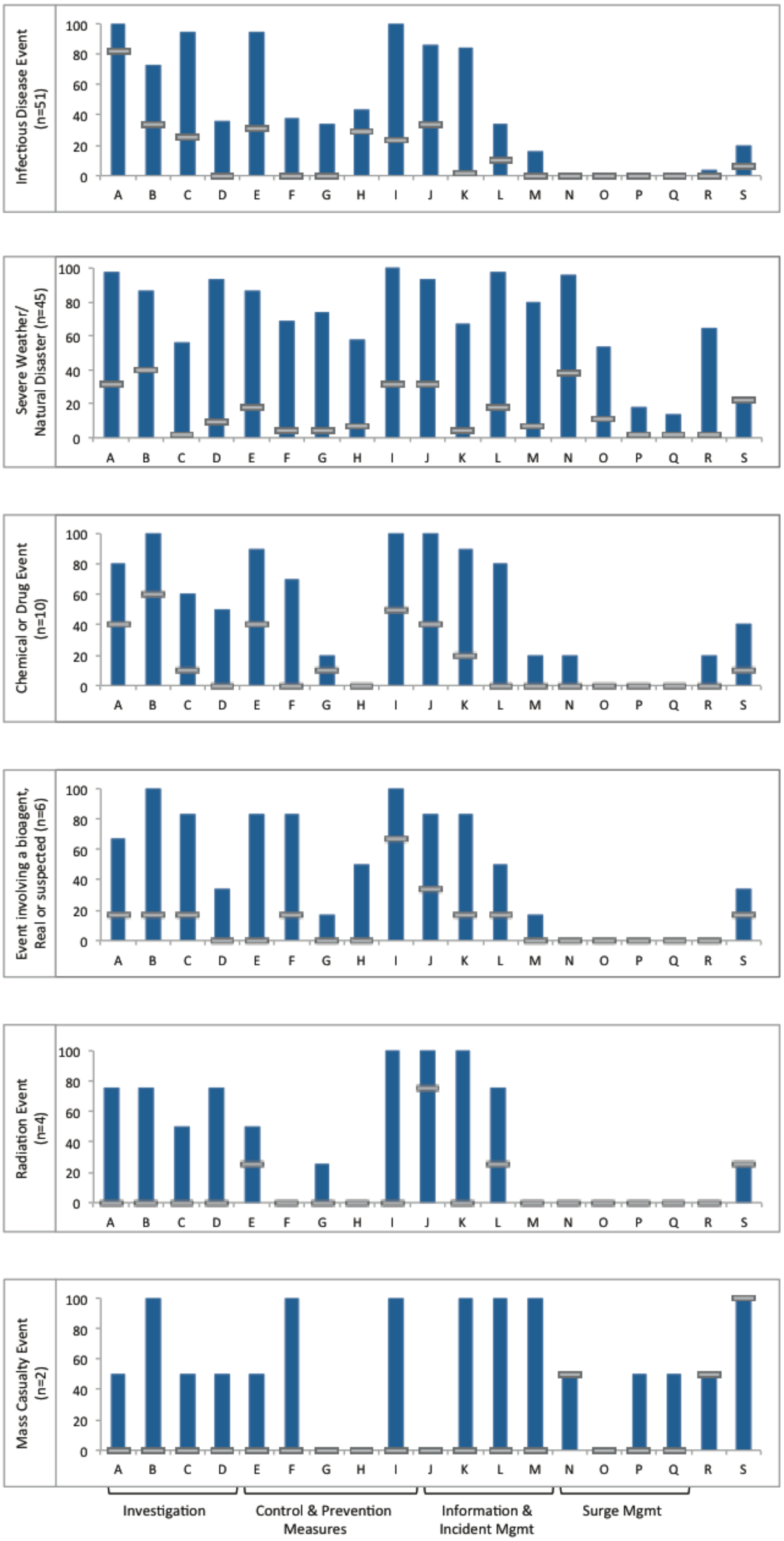


Figure 3. Public health response activities, by event



Domain 1: Investigation Activities

A Public health surveillance & epidemiology
B Environmental or product investigation
C Public health laboratory testing
D Assessing public health/medical capacity*

Domain 2: Disease Control & Prevention Activities

E Non-pharmaceutical interventions
F Responder safety/health management*
G Medical material management*
H Medical countermeasure dispensing*

Domain 3: Information and Incident Management

I Information sharing & management
J Emergency public information & warning
K Consulting subject matter experts
L Emergency operations management*

Domain 4: Surge Management

M Volunteer management*
N Mass care and sheltering*
O Evacuation*
P Fatality management*
Q Medical surge*

Domain 5: Community Resilience

R Community recovery*

Other identified activities

S Other Activities

* Difference between infectious disease and non- infectious disease events significant at $p<0.05$

Figure 4. Public health system response profile, by event

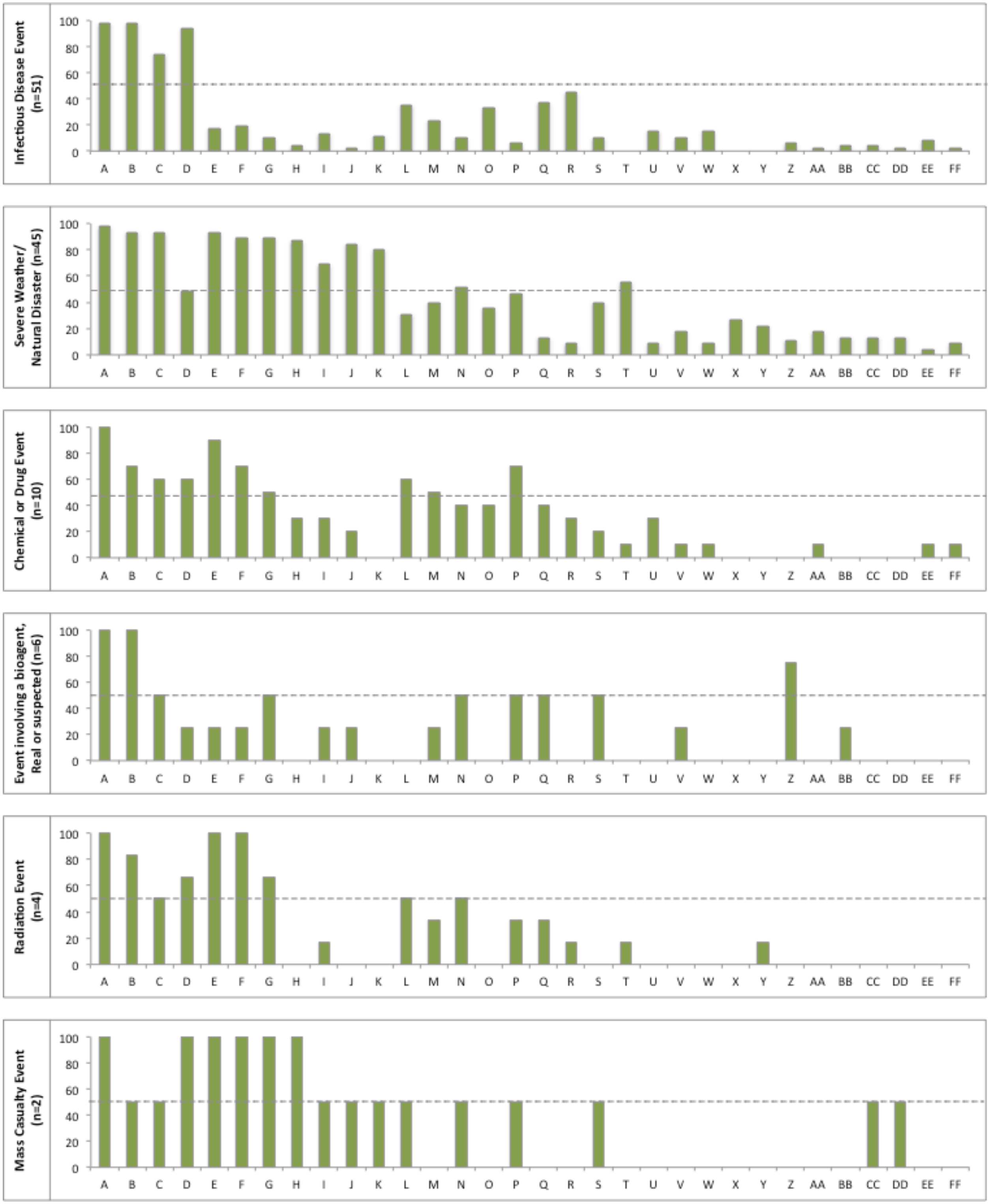


Figure 4 – Key

Key	Organization Type	Signif
A	Local Public Health Agency (includes Environmental Health)	
B	State Public Health Agency	
C	Healthcare Providers	
D	General Public	*
E	First Responders	*
F	Law Enforcement/Public Safety	*
G	Emergency Management Agency	*
H	Red Cross	*
I	Agency serving vulnerable populations (Social Welfare, Mental Health)	*
J	Critical Infrastructure (Govt or Non-Govt)	*
K	Volunteer Groups/Management (CBO, FBO, Medical Reserve Corps)	*
L	Employer or Private Business	
M	Media	
N	Political/Public Administration Office	*
O	Education (K-12, Preschool)	
P	Environmental and/or Natural Resources Agency	*
Q	Federal Public Health Agency (CDC)	*
R	Laboratory (Clinical or Commercial)	*
S	Public Information Office	*
T	Disaster Relief Agency	*
U	University/Academic Institution	
V	Regional Health & Medical Entity	
W	Food and Agriculture Agency	
X	National Oceanic and Atmospheric Administration (NOAA)	*
Y	Animal or Veterinary Entity	*
Z	Pharmaceutical and/or Drug Agency	
AA	Subsidiary health department	*
BB	Insurers/Payers/Finance (Govt, Private)	
CC	Medical Examiner and/or Coroner	
DD	Ad-Hoc Disaster Assistance Centers	*
EE	Legal Support	
FF	Expert Consultant	
GG[1]	Ports of Entry/Travel	
HH[1]	Professional/Trade Associations	
II[1]	Community Center	
JJ[1]	Poison Control	
KK[1]	Vector Control Agency	
LL[1]	International Governmental Agency	
MM[1]	Other Regulatory Agency	
NN[1]	One-Time Participants	
OO[1]	Housing Agency	
PP[1]	Tribal Entity	

[1]Not shown in figure, mentioned in <5% of cases

* Difference between infectious disease and non infectious disease events significant at p<0.05

Chapter 3: Public health response systems in action: Learning from health departments' experiences with acute and emergency incidents

Introduction

Described as "medical detectives," public health professionals have a long and storied history of investigating acute, sometimes mysterious, incidents of adverse health events and providing practical recommendations to prevent further illness. Traditionally, field epidemiology has been at the center of this practice, and infectious disease outbreaks have been the typical subject of investigation [1–3]. Over the past decade, however, the expectations for public agency response capabilities and the situations requiring public health action have broadened considerably. In some ways, this broadening was a direct consequence of the anthrax attacks within the United States in 2001 and the resulting concerns about bioterrorism. Expectations have been shaped further by subsequent emergencies, including the emergence of Severe Acute Respiratory Syndrome (SARS) in 2003 and the extraordinary destruction caused by Hurricane Katrina in 2005, which served to solidify a greater appreciation of the role of public health in a variety of acute event scenarios [4, 5]. The now commonly-used terms, "public health emergency" and "all-hazards preparedness," attest to belief that health departments have a responsibility for attending to acute health threats of any type or origin [4, 6].

As expectations have expanded, the need to strengthen public health systems' capacity to respond to any hazard has been at the center of many policy discussions [7]. However, the evidence base to support this priority has lagged behind. There is still little agreement on how to measure, let alone improve public health response performance [8, 9]. A number of challenges have been cited as barriers to research advancement in this field, including the infrequent nature of large-scale public health emergencies, the heterogeneity of emergency events and of public health delivery structures, the challenges with access to incident leadership during real-world emergencies, and the difficulty of identifying a comparison group or constructing a counterfactual of what might have occurred if particular public health interventions had not taken place [8, 10–12]. As a result, researchers have been limited in their use of statistical methods to test hypotheses, reach generalizable conclusions, and isolate factors that are likely to have the greatest impact on response capacity. Additionally, because catastrophic events are, thankfully, infrequent, the majority of the measurement literature in this field has focused on preparedness rather than on response -- on identifying and measuring the inputs to preparedness rather than the variations in response performance. What we do know about public health emergency response is largely derived from simulated emergencies (e.g. exercises or drills), with a primary focus on bioterrorism or pandemic influenza [8]. By relying on an evidence base that draws from a narrow set of threats, we run the risk of overemphasizing the capabilities and resources required for those incidents while neglecting those that may be essential in other scenarios [13].

These limitations pose serious challenges to public heath authorities who seek to evaluate their own response capacity and to direct resources towards evidence-based improvements. They also hinder the ability of stakeholders to keep public health agencies accountable to their mission. In the case of acute events, the level of public health performance can make a difference in the number of lives saved, the illnesses or injuries averted, and the economic and social costs to a community. Consequently, the importance of improving the evidence base concerning performance standards and measures in this field cannot be overstated.

While it is essential that researchers continue to learn from real or simulated catastrophic events and to improve the methods for this type of inquiry, new approaches that might overcome recognized barriers to data collection and shed light on the important performance and policy questions could prove useful. This study is one such attempt. It features two major departures from the current paradigm: (1) concentrating our efforts on characterizing responses to real-world events rather than preparedness efforts to hypothetical scenarios; and (2) comparing response features across incidents rather than identifying lessons learned from single isolated incidents. Guiding this approach is a supposition that, while each event is in some ways unique, the number and type of response activities are finite; therefore, through comparative analysis, we can learn about commonalities in the *response patterns* that could improve predictions and expectations regarding the resources and capabilities required to respond to future acute events. To investigate this theory, we developed a collection of highly structured data on more than 120 real-world acute incidents -- not just disasters -- which together represent the broadest set, to date, of events that have stressed the public health system in the United States. By pooling data across diverse incident contexts and types, we vastly increase the number of opportunities for learning [14–16]. Our hope is that this research can serve as a starting point for the development of evidence-based forecasts that might help shape researchers' and practitioners' expectations for public health behavior during urgent events and identify situations in which a governmental public health response has deviated from these expectations. Such "surprises" can then provide valuable opportunities to improve and update our understanding of response performance by pointing to: (1) a lack of sophistication in our predictive models, (2) adaptive response behaviors, or promising practices, that could be applied in other situations to beneficial effect, or (3) unnecessary variation associated with inefficiencies that may affect the health of a community or the reputation of public health agencies.

Conceptual Framework

Adopting the maxim that "all emergencies are local", and driven by the goal of characterizing the greatest number and diversity of events practicable, we focused this research on describing the public health response systems from the perspective of the local health department. Therefore, we examined three domains through structured interviews with public health authorities involved in response efforts, including: (1) key characteristics of the acute event context, (2) the number and type of public response activities initiated using the CDC Public Health Preparedness (PHEP) capabilities as an organizing framework, and (3) the number and type of organizations contributing to the public health response activities. The domains selected for this investigation were informed by a study of the organization and delivery of local public health services during normal operations by Mays *et al*. (2009), which employed similar measures in the expectation they could reasonably be expected to influence performance and outcomes [17, 18]. We view these response measures as intermediate outcomes between an exposure (i.e. the urgent event) and the final outcomes of interest (e.g. exposures, illnesses, disabilities, deaths) [19].

We expect that the community context, including the availability of local resources and public preferences for the delivery of services, will influence aspects of how the public health system responds to an acute event [17]. However, we posit that the character of the event itself will trigger distinguishable response patterns, regardless of the community context. To test this hypothesis, we compared response measures for traditional infectious disease investigations with less commonly described responses to non-infectious disease events. We also examined response patterns across six CDC-defined hazard categories: infectious disease events, severe weather and natural disasters, bioterrorism events, mass casualty events, chemical emergencies, and radiation emergencies [20]. The resulting profiles provide the first account of the public health response system using quantitative data, which can be used to compare the public health response based on key characteristics and to generate ideas for improving future performance.

Methods

Study design

This research uses a mixed-methods approach. Quantitative and qualitative data on urgent event and response characteristics were collected through structured telephone-based interviews with health department representatives using a retrospective cross-sectional design.

Study population

Selection criteria

One of the primary aims of this investigation is to characterize how public health agencies and their community partners respond to urgent and emergency events at the local level. However, because no comprehensive source of data concerning such events exists, we chose to begin with a sampling frame of local health departments, and to ask recruited representatives to identify eligible events, which would be the subject of the interview. Selection criteria were applied at the level of the health department, the event, and the informant. First, at the level of the public health department, organizations were identified using the 2010 National Profile of Local Health Departments (Profile of LHDs), a national survey completed by more than 80% of the 2,565 local health departments in the United States [21]. We further limited our target population to organizations that serve a population of at least 50,000 individuals. These 963 health departments serve the vast majority of the United States population (89% of the population) and are more likely to have responded to an eligible event, thus improving sampling efficiency [21]. Second, at the level of the event, we asked well-informed health department representatives to select an "urgent event" that their health department had responded to since January 2009. An "urgent event" was defined as one whose scale, timing, or unpredictability overwhelmed or threatened to overwhelm routine capacity [6]. Because the concept of an urgent event is not widely understood or accepted, we also provided a list of possible event types to prompt and guide potential participants' thinking about appropriate events. This list included: infectious disease outbreaks or investigations, environmental contamination, accidental poisoning, severe weather or natural disasters, and other unusual acute public health incidents. Based on our interest in obtaining a wide range of real-world events that are not well characterized in the literature, we excluded events involving simulated emergencies (e.g. exercises or drills) and the 2009 H1N1 influenza pandemic. Third, at the level of the informant, health department representatives had to indicate that they were generally knowledgeable about the overall public health response to the selected event in order to be eligible.

Sampling design

Our initial approach was to employ a sampling strategy that would result in a representative sample of urgent events. However, this approach was not feasible because of the current unavailability of information regarding urgent public health events and the scope of this project. Therefore, our first sampling strategy involved oversampling local health departments that had experienced a recent urgent event (Sample 1, described below). Once this source had been depleted, our second strategy involved randomly sampling eligible health departments in an effort to avoid selection biases associated with our preconceived notions of urgent events (Sample 2, described below). Last, two pilot samples were identified to test the structured interview tool and to assess recruitment rates (Pilot Sample, described below).

Sample 1. The first sampling strategy leveraged prior knowledge of local health departments' recent involvement in urgent event response efforts, thus oversampling eligible organizations and improving the efficiency of sampling. We used data from the Profile of LHDs, in which a sub-set of participating agencies were administered a survey module that asked whether their agency had responded to an "all-hazards emergency" between January 2009 and late 2010. All 171 local health departments that responded affirmatively to this question and that met our other inclusion criteria (i.e. the event was not 2009 H1N1 influenza and the health department served a population of at least 50,000) were included in Sample 1.

Sample 2. Because we were unable to obtain the desired study sample size through the strategy outlined in Sample 1, we employed a second sampling frame to identify an additional 169 LHDs. Again using the 2010 Profile of LHDs, we selected from all participating health departments (serving a population of at least 50,000 individuals) using a population proportional to size probability sampling strategy, in an attempt to ensure that the health departments serving smaller populations were not oversampled. The number of health departments sampled was based on the response rate from Sample 1.

Pilot Samples. The first pilot study included a convenience sample of four LHDs with whom the researchers had a professional connection. The goal of this pilot was to test the data collection instrument with a variety of hazard types and with health department representatives serving different population sizes and governance structures. A second pilot sample of nine health departments was identified to assess whether participation rates might be improved by asking health departments about a specific recent event that affected their community. These organizations were identified based on their involvement in incidents reported through an online disease outbreak alerting system, HealthMap, which aggregates information on incidents from a wide variety of sources [22]. Health departments were selected by applying a random interval to the list of events in the database.

Recruitment

Study recruitment and data collection proceeded in rounds, starting in March 2012 and ending in October 2012. In the initial rounds of recruitment, study invitations were emailed to preparedness coordinators and health officers for sampled LHDs, along with a short description of the survey goals via email from the office of the Principal Investigator of Cal PREPARE, a CDC Preparedness and Emergency Response Research Center at the University of California, Berkeley. Based on the input from our practice-based advisory committee, these two categories of professionals were expected to be the most knowledgeable about the overall response to urgent events. Through this initial recruitment process, we learned that for many health departments, communicable disease control directors or epidemiologists would be the best informed about the overall response to an infectious disease event. As a result, after approximately one-quarter of our sample had been recruited, we shifted our outreach strategy and targeted either (1) the preparedness coordinator, or (2) the communicable disease director or epidemiologist, in an effort to identify a range of infectious and non-infectious disease events. Each round of recruitment lasted six weeks, during which time, individuals were sent the initial email invitation and study description, a reminder postcard by mail, three email reminders, and a telephone or voicemail follow-up. During the recruitment process, individuals were informed that they could forward the invitation to another individual within the health department who might be better positioned to participate, and that multiple individuals could participate in a single interview. Individuals were also given an option to opt-out of recruitment and to provide a reason for non-participation.

Interested individuals were directed to a web-based screening survey, administered through Qualtrics©, which provided instructions on selecting an urgent event that would be the subject of the interview, requested detail on the selected event, and asked whether they were generally knowledgeable about the overall response to this event. Upon submission of this screening survey, individuals were further directed to a web-based appointment scheduling system, ScheduleOnce©, where they could propose a convenient day and time for the interview and provide contact information. Appointment slots were available from 8am-6pm Pacific Time, Monday through Friday, from March through early October 2012, with earlier appointments available upon request. Research staff reviewed screening forms and appointment requests within 24 hours of submission, and either approved the interview time or followed-up with interested individuals, if additional information was required. A confirmation email with interview details (e.g. contact information, length of interview) and a brief interview guide outlining the general interview domains were emailed to confirmed participants. A final email reminder was sent to participants 24 hours prior to the agreed-upon interview time.

As an incentive for participation, all participants were offered a customized report that would summarize their interview and provide a comparison to other participating health department(s) that had experienced a similar event (the comparison group would be anonymous), provided the data were available. Participants were also entered into a raffle to receive monetary prizes, including a top prize equivalent to $500 and five runner-up prizes equivalent to $50, which could be put towards conference registration, UC Berkeley apparel, public health books, or other approved preparedness-related items. Incentives were selected based on input from pilot participants and Cal PREPARE practice-based advisory committee members.

Measurements and Instrument

Instrument

Interviews were conducted by phone using a structured interview tool, which included questions related to the three primary research domains, including: (1) key characteristics of the acute event context, (2) the number and type of public response activities initiated using the CDC Public Health Preparedness (PHEP) capabilities as an organizing framework, and (3) the number and type of organizations contributing to the public health response activities. Each of the measures is described in detail, below. This tool included a combination of structured and open-ended response options. The questions and response options were iteratively developed and refined through testing with over 100 case studies reported in the peer-reviewed literature, revised for use in a telephone-based interview setting, and then further revised after pilot testing with four local health departments. The final interview guide is available as a **Supplemental Material**.

Three interviewers (two primary interviewers and one back-up interviewer) were extensively trained on the intent of each question in the instrument, administration protocols, and response coding. To improve administration consistency and inter-rater reliability, study personnel went through a training process in which they first observed interviews, conducted mock interviews using realistic case material, and then conducted supervised interviews. Another interviewer also recorded data during these training interviews, and all discrepancies in coding and administration were discussed and resolved. Additionally, any questions on interpreting and coding interview responses were discussed throughout the data collection period. After all interviews had been completed, each of the two primary interviewers reviewed the others' completed data collection tools to ensure that coding decisions were consistently applied. Audio recordings of interviews were used for validation, as needed.

Measures

Event characteristics. Each interview was characterized with respect to a number of event features, which were selected with the goal of building a common operational picture that could allow for meaningful comparison across disparate events. Accordingly, each interview was assigned to one of six specific hazard categories, as defined by the CDC Emergency Preparedness and Response website, including: infectious disease outbreaks and incidents, natural disaster or severe weather events, bioterrorism events, mass casualty events, chemical emergency events, or radiation emergency events [20]. An additional "other" category was developed for events that could not be easily categorized using the initial six hazard categories. For the purpose of certain analyses within this investigation, these categories were further collapsed into two groups, (1) infectious disease events, including bioterrorism and infectious disease outbreak events, and (2) non-infectious disease events, comprising the remaining hazard categories. Interviewers asked participants about additional hazard details, as appropriate for each category. For example, for infectious disease events, the disease agent and mode of transmission were recorded, whereas for severe weather or natural disaster events, the type of severe weather event was noted (e.g. hurricane, flooding, severe winter weather). For all interviews, regardless of the hazard category, the following event details were summarized: the duration of the public health response, the number of individuals contacted for investigating illness or exposure, the number of probable or confirmed cases, the number of severe cases (requiring hospitalization or resulting in death), and the number of persons receiving medical countermeasures as part of the public health response. Additionally, for each interview, the geographic location and populations most affected by the event were also recorded.

Public health response activities

We used the CDC Public Health Preparedness Capabilities (PHEP Capabilities) framework and definitions as the basis for characterizing the public health activities carried out in response to the hazard [23]. This framework, developed through a review of legislative and executive directives, expert panel processes, and extensive stakeholder engagement, identifies and defines 15 types of services (grouped in five domains) that public health systems could be expected to deliver during emergencies. We deviated from this framework for the purpose of data collection in three key ways. First, we added four categories that emerged as important public health response activities through previous related work and pilot testing but that were underspecified in the CDC PHEP Capabilities document. These categories included: environmental investigations, evacuation, consulting subject matter experts, and assessing medical and public health response capacity. Second, we eliminated the "preparedness" category, which, during pilot testing, proved to be a confusing concept in the context of a specific response. The third major deviation from the PHEP Capabilities framework was the collection of "other" activities that participants felt were important aspects of the response that had not otherwise been captured in the interview. Without explicitly stating that we were asking about PHEP Capabilities, interviewers listed each of the 19 response activity categories (14 original PHEP Capabilities, four additional categories, and an "other public health response activity" category) and asked participants to indicate if any related activities were initiated in response to their selected event, regardless of which agencies were responsible for these efforts. Additionally, participants were asked to identify which of the response activities were essential, defined as "absolutely necessary to the overall response." A summary score was calculated by summing the total number of public health response activities initiated during an event (between 0 and 17 activities). Based on researchers' interests, additional details were collected on certain response activities, including epidemiologic investigation and surveillance, non-pharmaceutical interventions, and medical countermeasures, results not described in this paper. These questions were developed through a review of the outbreak investigation and field epidemiology literature [2, 24, 25].

Organizational partners

Organizational partners were defined as entities that contributed to any of the aforementioned public health response activities. Therefore, interviewers asked participants to identify the organizations and agencies that contributed to each identified activity category (including their own organization). These entities were recorded using an initial list of 35 pre-identified organization categories, derived from CDC PHEP reporting requirements, the literature describing public health system characteristics, and previous related work by the authors. Any agencies that did not immediately seem to fit into these designated categories were coded as "other" and further described in an open text field. Once the study was completed, both the original and "other" lists were examined to identify natural groupings based on organizational function; these list were reviewed by three experts in preparedness and organizations, and a final list of 41 organization categories was developed [17, 26–28]. After this list was finalized, all interview tools were reviewed again to ensure consistency in organizational coding (A description of the organization types and the categorization process is available as a **Supplemental Material**). Three measures were developed from these data. The first measure, "any involvement", is a dichotomous variable that indicates whether entities from each of the 41 organizational categories contributed to *any* of the 17 public health response activities. The second measure, "extent of involvement", provides a proportion of the public health response activities contributed by each type of organization, when that organization type had any involvement. For each case in which a specific organization type had any involvement, the "extent of involvement" was calculated as the:

$$Extent\ of\ Involvement\ =\frac{Number\ of\ Activities\ Contributed\ by\ Each\ Organization\ Type}{Total\ Number\ of\ Activities\ Performed\ during\ the\ Urgent\ Event}$$

Additionally, a summary measure of the total number of organizational categories mentioned in the interviews was calculated (between 0 and 41 organizations).

Other qualitative measures

After each interview, study personnel were encouraged to write analytic notes or "memos" regarding their general impressions, reflecting on the health departments' primary concerns during the event, unique aspects of the event or response not otherwise captured in the data collection tool, and recurring topics or relationships.

Alternate explanatory variables

Because we expected that the community context and local health department capacity also influences the character of the public health response system, we also conducted an exploratory analysis to assess this relationship [17, 18]. In our conceptual model, these factors have the potential to have a direct effect on the relationship between the exposure (urgent event) and the intermediate outcomes explored in this study. Alternatively, they could act as confounders or effect modifiers. Using data from the 2010 Local Profile of LHDs, we assessed whether the number of response activities and partners varies by the population size served by a health department, health department expenditures, and number of full-time staff [21]. Additionally, we examined whether the response activities and response partners vary based on the nexus of public health authority (at the state or the local level).

Statistical issues

Data recorded on paper-based interview tools were entered electronically into the web-based program, Qualtrics, using double data entry; the data were managed and analyzed using Stata 11 (StataCorp LP, College Station, TX) and merged with organizational data from the Profile of LHDs [21]. Discrepancies identified through double data entry were reviewed and resolved. Distributions of event characteristics, response activities, and response partners were calculated and event profiles were developed to allowing for visual comparisons across the six hazard categories. For event and response measures, the differences between infectious disease and non-infectious disease events were assessed using *t* tests or chi-square tests, as appropriate. Multiple linear regression models were employed to assess the association between organizational factors and response outcomes, controlling for the event type. Information from qualitative memos and open-ended responses was reviewed and organized into themes.

Based on our power analyses, we decided to recruit at least 120 health departments. With this sample size, we expected to have power of 80 percent to detect significant differences of 25 percentage points or more between infectious disease and non-infectious disease events for the response measures of interest.

The protocol for this study was approved by the Committee for the Protection of Human Subjects at the University of California, Berkeley.

Results

Sample demographics

Of the 354 recruited local health departments, respondents from 123 health departments completed an interview, resulting in a 35% response rate. A flow diagram summarizing recruitment, screening, and enrollment is provided in **Figure 1**. The 231 non-responding local health departments included: agencies that were not eligible because they did not have an urgent event that met study criteria (9% of non-respondents), that enrolled in the study but were lost to follow-up during the course of data collection (9%), that declined for reasons provided in **Figure 1** (12%), and that provided no response to study recruitment requests (71%).

Respondents represented health departments in 38 of the 48 US states targeted for recruitment, illustrated as **Figure 2**, with a diversity of community and public health agency characteristics (see **Table 1**). These agencies served populations from 50,000 to several million residents, reported annual expenditures ranging from $1 to more than $500 per capita, and had staffing levels between 10 and more than 1,000 Full-Time Equivalents. Nearly three-quarters of respondents represented health agencies that operate as units decentralized from state health agencies (i.e. locally governed), with responsibility for a geographic jurisdiction defined by county boundaries. Overall, compared to non-respondents, responding agencies were significantly more likely to serve a larger population, have more expenditure per capita, and have more Full Time Equivalent staff (for all values, $p<0.05$).

Informant and interview characteristics

A summary of respondents' functional roles is provided in **Table 1**. The most widely represented positions were those actively recruited, as described in our research protocol, with nearly two-thirds of interviews involving preparedness and response coordinators/directors and almost half involving communicable disease staff (epidemiologists, directors, nurses).

Interviews typically lasted nearly one hour, ranging from 27 minutes to 120 minutes. On average, interviews focusing on infectious disease events were significantly shorter than those focusing on non-infectious disease events ($p<0.05$).

Event Characteristics

Event details

The urgent events included in our study primarily involved infectious disease investigations and severe weather or natural disasters, with each constituting approximately 40 percent of the total. The most commonly reported infectious disease events involved norovirus, *Bordetella pertussis* ("whooping cough"), salmonellosis, and shiga toxin-producing *Escherichia coli* (such as *E. coli* O157:H7). Frequently described natural disasters included severe wind and rain storms, such as hurricanes and tropical storms, severe ice and snow storms, tornados, fires, and floods. Our event set also includes incidents involving chemical exposures, misuse of prescription or illegal drugs, suspected or confirmed exposure to biological agents, radiation, mass casualties, and anticipated mass-gatherings. Additionally, one incident involved a community that received displaced persons after the devastating earthquake in Haiti and saw cases of cholera imported from the impacted region. This interview was characterized as a "complex event" because the incident involved causes that fell into multiple categories. Additional details on the types and frequencies of cases are provided in **Table 2**.

When informants were asked how frequently their health department responds to a similar event on the same scale as the incident they selected for the interview, more than half indicated that this was the only event of its kind in recent history (29% of cases) or that something similar happens once every few years (29%). Other events occurred with a greater frequency, from one to two times per year (28%) to three or more times per year (13%).   Every event in the following event categories was considered to occur very infrequently (i.e. less than once per year): mass casualty events, complex events, technological emergencies, and anticipated events.

Other indicators of event severity

Health departments' respondes to events varied widely (see **Table 3**). For example, the shortest response duration was approximately five hours, in the case of a white powder incident, while the longest response lasted multiple years in the case of the Deepwater Horizon oil spill. The number of individuals within the community contacted by health departments and their partners to assess illness or exposure ranged from 0 to 11,000 individuals within the community, resulting in the identification of a mean of 37 confirmed and probable cases, of which a mean of three cases resulted in hospitalization or death. A t-test comparison of the log-transformed variables, *duration of response* and *number of probable or confirmed cases*, revealed that infectious disease events involved significantly more cases ($p<0.05$) than did non-infectious disease events. After excluding events involving biological agents, which tend to be very short in duration, the *duration of response* was also significantly longer in infectious disease events ($p<0.05$).

All severe weather and natural disaster events directly or indirectly resulted in the disruption of community infrastructure or services, including water, sewage, electricity, telecommunications, roads or transportation, as well as the direct delivery of public health and medical services. On average, four types of services were disrupted in these severe weather events. With the exception of technological emergencies, other types of events rarely involved an interruption of community services other than those provided by public health, which were postponed or cancelled due to staff diversions for response activities, something that occurred in nearly a quarter of cases not involving severe weather events.

Populations affected

Overall, the populations considered to have been "disproportionately affected" during urgent events included: persons with chronic medical conditions (23%), senior citizens (20%), or children and adolescents (19%), and low-income individuals (18%). Infectious disease events were significantly more likely to affect occupational populations and children or adolescents ($p<0.05$), whereas non-infectious disease events were more likely to affect the general population at-large as well as vulnerable populations, including those with chronic medical conditions, low-income individuals, and persons with special communication, transportation or supervision needs ($p<0.05$).

Public Health Response Activities

In response to the urgent events included in our study, the range of public health activities initiated by response systems varied considerably (**Figure 3**). Of the 19 activity categories, urgent event response efforts involved between 3 and 18 types of activities, with a mean of ten activities per event. The response activities most commonly initiated were those related to: information sharing and management (100% of events), public health surveillance and epidemiology (98%), emergency public information and warning (89%), non-pharmaceutical interventions (88%), environmental or product investigation (82%), consulting subject matter experts (79%), public health laboratory testing (74%), and emergency operations management (65%).

Activity profiles for each of the six event categories (**Figure 2**) provide a summary of the frequency and distribution of response measures by event type. Non-infectious disease events in our study resulted in a significantly greater number of response activities compared to infectious disease events. This difference was most dramatically illustrated when comparing the activity profile of infectious disease events (Figure 2, top box), in which seven types of activities were initiated in more than half of the events, with severe weather and natural disaster events (Figure 2, second box from top), in which 16 types of activities were carried out in more than half of events. In addition to the number of activities initiated, there were also significant differences in the character of the response activities. As expected, dispensing medical countermeasures, including vaccination and post-exposure prophylaxis, was more likely to occur during infectious disease events ($p<0.05$). In contrast, 11 different types of activities were significantly more common in non-infectious disease events, including: assessment of public health or medical capacity, responder safety and health measures, medical material management and distribution, emergency operations management, volunteer management, mass care and sheltering, fatality management, medical surge, evacuation, and community recovery ($p<0.05$). Further, these differences clustered by activity domain. Whereas most investigation and information-management activities occurred at a similar frequency between infectious and non-infectious disease events, differences were common in the following domains: disease control and prevention, surge management, and community resilience domains. Because severe weather and natural disaster events constituted a majority of the non-infectious disease events, we conducted a sensitivity analysis to assess the robustness of the results. After excluding severe weather and natural disaster events, we found that infectious disease and non-infectious disease events did not differ significantly with respect to the number of response activities, and that the only differences in type of activity consistently present were: dispensing of medical countermeasures, which was still more common in infectious disease events, and emergency operations management, volunteer management, and mass care and sheltering, which remained more common in the non-infectious disease events ($p<0.05$). Additionally, after excluding severe weather and natural disaster events, two new activities appeared to be more common to infectious disease events, including epidemiology/surveillance and laboratory testing ($p<0.05$).

Essential Response Activities

Our measure of *essential response activities,* illustrated as horizontal gray bars in **Figure 3**, provides a summary of activities that were perceived as absolutely necessary to the overall response. For the urgent events in our study, the most common essential activities were: epidemiology and surveillance for ***infectious disease events***; environmental health and mass care and sheltering for ***severe weather events;*** environmental investigations and information management for ***chemical events;*** information management for ***events involving biological agents***; public information and warning for ***radiation events***, and "other" for ***mass casualty events.*** These other activities included patient transport and coordinating family assistance centers. The essential response activities also demonstrate that, despite being frequently initiated across all event contexts, some response measures are more likely to be viewed by responders as "absolutely necessary" for a given event type. For example, while epidemiology and surveillance activities were initiated almost universally during urgent events, they were much more likely to be considered essential for infectious disease events than for other event categories. Similarly, although information sharing and management activities were initiated in all events, they were most likely to be considered essential in those involving bioterrorism and chemical agents.

Participants identified "other" public health activities that were carried out in response to their event but were not captured by our pre-defined activity categories, including those related to: restoring community confidence after an event (e.g. community meetings, counseling individuals), enabling individuals to follow disease prevention and health promotion activities (e.g. obtaining food stamps after food disposal orders, providing financial assistance if ill or infected persons were excluded from work due to risk of disease transmission, providing housing for individuals removed from their homes), contributing to resource coordinating centers to assist affected persons access services and permits from multiple agencies after an event, and assessing legal compliance and breaches of protocols.

Public Health Response System

Overall, public health response systems were comprised of 3 to 25 types of organizations, with a mean of 10 public health system organizations (**Figure 4**). The types of organizations mentioned as participating in more than half of urgent event responses in our study included: local public health agencies, including environmental health (98% of cases); state public health agencies (92%); healthcare providers (78%); members of the general public, including cases, contacts and family members of cases, and other individuals (70%); first responders, including emergency medical services, hazardous materials, and fire (58%); and law enforcement and public safety agencies (56%).

Overall, infectious and non-infectious disease events differed with respect to the numbers and types of public health system partners. The response systems for non-infectious disease events were comprised of significantly greater numbers of organization categories ($p<0.05$). We identified 17 organization types that were significantly more common in non-infectious disease events, including: first responders, law enforcement or public safety agencies, emergency management agencies (local or state), the American Red Cross, agencies serving vulnerable populations (including social welfare and mental health), critical infrastructure, volunteer groups (including medical reserve corps and community- or faith-based organizations), employers or private businesses, persons from political or public administration offices, environmental or natural resources agencies, public information offices, disaster relief agencies, the National Oceanic and Atmospheric Administration, animal or veterinary entities, subsidiary health departments, and "ad-hoc" disaster assistance centers, such as shelters and family assistance centers ($p<0.05$). In contrast, infectious disease response systems were significantly more likely to report involvement by three organization types, including the general public, commercial or clinical laboratories, and federal public health (i.e. CDC). We also conducted a sensitivity analysis to assess the robustness of our findings after excluding severe weather and natural disaster events. We found that the difference in the number of response partners between infectious disease and non-infectious disease events remained after excluding severe weather events ($p<0.05$). However, only half of the previously observed differences in the types of response partners remained, including: general public, first responders, law enforcement, emergency management, American Red Cross, critical infrastructure, and laboratories. ($p<0.05$). Additionally, after excluding severe weather and natural disaster events, two new differences in response partners appeared; involvement of ports of entry entities were more common in non-infectious disease events and involvement of state public health was common in infectious disease events ($p<0.05$).

For each incident, we also calculated the *extent of involvement* or the proportion of initiated response activities to which a participating agency contributed. The vast majority of partner organizations contributed to a very limited proportion of the overall response activities. For example, volunteer organizations were primarily involved in mass care and sheltering or volunteer management activities, whereas the involvement of environmental or agricultural entities was mostly limited to environmental investigation and information sharing. Of forty-one organization types, only five contributed to more than ten percent of response activities, including: local public health agencies, which contributed to a mean of 79 percent of response activities, state public health agencies (38% of response activities), healthcare providers (21%), first responders (14%), emergency management agencies (13%), and law enforcement agencies (11%).

Role of public health in the response system

Informants felt that public health played a "lead role in the overall response" to half of the events in this study, a joint-role in approximately one-third of events, and a supporting role in the remaining events. However, the public health role varied tremendously by type of event, whereby public health was considered to play the lead role in 100% of the radiation and complex emergency cases, 94% of infectious disease cases, 33% of events involving a bioterrorism agent, 30% of chemical events, 9% of severe weather or natural disaster events, and none of the technological emergencies or anticipated events.

Community and Public Health Agency Characteristics

Respondents from health departments in which governmental authority is centralized at the state level or where authority is shared between state and local entities were significantly more likely to choose non-infectious disease events as the subject for the interview, compared to health departments that are decentralized from the state health department ($p<0.05$). The public health system partners more likely to be activated in health departments with centralized or shared systems mirrored those more likely to be involved in responses to non-infectious disease events. However, when the analysis was stratified by infectious and non-infectious disease event categories, the number of response partners and response activities no longer differed by the locus of public health authority. However, we found that during infectious disease events, certain types of entities were more likely to be mentioned by health departments with a centralized or shared structure, including ad-hoc disaster assistance centers and subsidiary local health departments, whereas local health departments were significantly more likely to be mentioned by representatives from decentralized health departments. No significant differences in the types of organizational response partners were identified for non-infectious disease events. With respect to response activities, decentralized health departments were more likely to report conducting laboratory activities during infectious disease events and environmental or product investigation during non-infectious disease events.

To assess the independent effect of agency characteristics on the response structure and function, multiple linear regression models were used to assess the relationship between the community and agency measures (predictor variables: size of the population served by a LHD, number of FTEs, and annual per capita expenditures) and response measures (outcome variables: number of organizations involved in the public health system response, number of response activities initiated during the response) controlling for the type of event (infectious disease versus non-infectious disease). Each of the six models included a single predictor and outcome variable, controlling for the type of event. We use the natural logarithm of each predictor variable and employed robust standard errors in the statistical models to minimize the effects of outliers and heteroskedasticity. Controlling for the type of event, only the models including the number of full time staff were significantly and correlated with the number of response activities ($F=37.88$, $p=0.005$) and the number of partners ($F=57.88$, 0.016). This correlation indicates an independent and inverse correlation between the number of public health department staff and the number of organization and activities activated during an event.

Response reporting and dissemination

Eighty percent of respondents indicated that their health department developed a report describing their response efforts. Approximately two-thirds of these health departments developed after-action reports, which were disseminated internally (66% of AARs), to contributing agencies (46%), or to the state health department (37%). In only 11 instances was a summary report widely disseminated, either in the peer-reviewed literature (4% of all cases), in the *Morbidity and Mortality Weekly Report* (3%), or through the Department of Homeland Security Lessons Learned and Information Sharing web portal (LLIS, 2%)

Discussion

Our study provides a rare inside look at the response operations of health departments and their community partners during a remarkable range of acute incidents. Public health representatives described their experiences responding to more than 120 incidents involving unusual clusters of illness, unexpected exposures to hazardous substances, or the sudden loss of infrastructure that we rely on for healthy communities. Regardless of the character of the event or the populations affected, nearly every informant portrayed a situation that compelled his or her public heath agency to work with a network of other organizations to take rapid action in an effort to mitigate, control, or prevent expected adverse heath consequences, often in highly stressful and politically charged environments with demanding expectations for performance. Our results reveal that these public health systems are responsive and adaptive to the character of the threat, resulting in differential activation of functions and partners based on the type of incident.

Our description of the public health response system, the first of its kind, offers practice-based evidence that may help shape expectations about the structural and functional characteristics of the public health response sytem. Our findings align with the National Health Security objective, "ensuring that all systems that support national health security are based on the best available science, evaluation, and quality improvement methods." [29]. The informants in this study described a system that differs dramatically from the one depicted in the 2008 Institute of Medicine (IOM) report, *Research Priorities in Emergency Preparedness and Response for Public Health Systems* [30]. The IOM report designated seven "key actors", which are visually displayed as inter-connected ovals in a diagram of the system, along with "unshaded ovals [that] represent the necessary overlap between the key actors as well as the many less obvious actors that play a significant role in integrating the public health preparedness system." A first clear difference between the public health preparedness system described in the IOM report and the one presented in our study concerns the number and diversity of organizations involved. The 41 types of entities identified by our informants, many of which have also been referred to in the published preparedness literature, shed light on the character and contribution of these "less obvious actors" [17, 26–28, 31, 32]. Additionally, our system profiles provide an indication of the frequency and circumstances with which these organizations might become involved in public health response activities. Furthermore, we found that some entities are likely to take part in a public health response of any nature, including public health agencies, healthcare providers, and members of the general public, whereas many other organizations are either infrequently involved in public health responses or typically have a role only under specific event circumstances. The American Red Cross provides a good example of an organization that was almost universally active in our severe weather and mass casualty events and sometimes involved in response to chemical or drug threats, but rarely took part in infectious disease or bioterrorism events. For public health agencies that infrequently experience certain types of events, and therefore have few opportunities to interact with particular partners, our findings may provide a new impetus for building or strengthening ties with related organizations. For all public health agencies, tailored outreach efforts should be informed by recognizing that the partner agencies described in our study, with few exceptions, lent their expertise or resources in a very limited proportion of the overall public health responses. As a result, only a fraction of response efforts will be salient to those organizations. Second, while the IOM report presented a system that appears static, our study found a system in which the numbers and types of response organizations, as well as the role of public health agencies, varied significantly, depending on the type of threat the health department faced. The public health response to severe weather events, for example, involved a much larger and more diverse set of partners than the responses to infectious disease events. However, public health departments were ten times more likely to serve in a lead role for infectious disease events compared to events involving severe weather. This lead role, and the responsibilities that come with it, could have great implications for the skills and training necessary for public health staff, particularly those in leadership positions. We also found that characteristics of the health department, most notably the number of full-time staff, influence the number of response activities and partners. Those health departments with a greater number of personnel initiated significantly fewer activities and engaged fewer organizational partners, regardless of the type of event. Previous research has shown that health departments have varying capacity to deliver routine public health services internally and that there are measurable differences in the extent to which agencies rely on external organizations for these functions [17]. It is, therefore, not surprising to learn that characteristics of the health department may also influence aspects of the response. To explain this finding, we hypothesize that organizations with higher staffing levels have greater internal capacity to carry out public health response measures and therefore rely on fewer organizations during a response. It is not clear why the other organizational characteristics that we examined (e.g. annual per capita expenditures, population size served by the health department) were not independently associated with the response outcomes, as we they also seem to be indicators of health department capacity.

From a research perspective, our findings could be of interest to a number of disciplines, particularly complexity science. Public health systems have previously been described as "complex adaptive systems"; however, this classification has yet to be examined empirically, as it has in disaster response more generally [33, 34]. As defined by Bovaird (2008), "complex adaptive systems" are characterized by a self-organizing network of organizations, comprised of a number of diverse organizations, in which power and control are highly dispersed, and where organizations are highly interconnected [35]. Using aspects of this definition, our findings suggest that, on the whole, severe weather events frequently elicit responses by systems with a *greater number* and *more diverse set of organizations*, and, therefore, may be considered more complex than non-infectious disease events. The severe weather response systems are more likely to include individuals from organizational cultures quite different from that of public health, including individuals with dissimilar training, expectations regarding authority and hierarchy, and beliefs about decision-making and how conflicts should be resolved. One implication of these findings is that responders in events involving particularly complex systems may be expected to experience predictable challenges to effective communication and coordination [36]. Public health preparedness could, therefore, benefit from being studied by researchers who study other complex organizational systems and who may be able to help build expectations around the character of these challenges, their consequences, and strategies for avoiding critical failure points during urgent events.

We used a capabilities-based approach as an organizing framework for conceptualizing public health response activities. This planning model, based on an assumption that preparedness can be achieved by directing resources towards building, testing, and improving defined priority areas, is at the core of the CDC "preparedness capabilities" that were used to characterize the response activities described by our informants. Consequently, our results complement the PHEP Capabilities by highlighting the circumstances in which related activities or functions might have particular relevance in practice. Not surprisingly, our study finds that certain types of events were much more likely to elicit response activities related to particular capabilities, and that the frequencies with which capability-related activities were performed did not necessarily equate with how "essential" that capability was to the overall event. For example, the epidemiology and surveillance capability was almost universally activated. However, it was more likely to be considered "essential" for certain types of events, particularly infectious disease events. Linking our results to the CDC preparedness capabilities framework may be of particular value to preparedness planners, for example, by guiding the selection of exercise scenarios that would be most likely to trigger activities related to the capabilities they seek to assess or improve. In addition to the original preparedness capabilities, we also asked participants about four additional categories of activities that were identified through our previous research [unpublished] and pilot testing as (1) important and (2) of a different character than the PHEP Capabilities. These activities included: environmental or product investigation, consulting subject matter experts, assessing public health or medical capacity, and evacuation. We believe that under-specification of important response functions can have serious consequences, particularly in an era of limited resources, where health departments are able to direct resources to only a limited number of preparedness improvements. Therefore, we believe that these activities may have a place in future discussions about what it means for a community to be prepared. Because informants mentioned these activities with such frequency, environmental and product investigations stand out as a particularly good subject for further discussion and consideration, perhaps even as a candidate for inclusion in a future iteration of PHEP Capabilities. Currently, environmental investigations are folded into the "epidemiology and surveillance" capability; however, the resources, staffing, and partners required for these activities are quite distinct from those required for epidemiology and surveillance. Furthermore, our study found that environmental investigations are frequently initiated across all urgent events and that this activity is considered to be "essential" in more than one-third of infectious disease, chemical, and severe weather incidents. Additionally, our informants mentioned a variety of "other" public health activities that were carried out in response to their event, but that they felt were distinct from the PHEP Capabilities, and may also merit further attention. These include activities related to: restoring community confidence after an event (e.g. community meetings, counseling individuals), enabling individuals to follow disease prevention and health promotion activities (e.g. obtaining food stamps after food disposal orders, providing financial assistance if ill or infected persons were excluded from work due to risk of disease transmission, providing housing for individuals removed from their homes), contributing resource coordinating centers to help affected persons access services and permits from multiple agencies after an event, and assessing legal compliance and breaches of protocols.

One of the ultimate goals of this research is to develop a typology that classifies events based on important sources of variation in the structural and functional aspects of the public health response system. By defining a few meaningful configurations common to public health response efforts, we hope to help public health managers develop and evaluate their preparedness programs. For example, while far from comprehensive or validated, our data might suggest three models of response. In the first model of response, most typical of infectious disease events, public health agencies serve in the lead role to the overall response; response activities and partners are more limited in number and type; the number of cases define event severity; and the epidemiology and surveillance function is considered most essential to the response. In the second model of response, most typical of severe weather and natural disasters, public health agencies serve in a joint or supporting role to the overall response; response activities and partners are more numerous and diverse; disruption to community infrastructure defines event severity; and environmental health and mass sheltering and care activities are considered most essential to the response. In the last model of response, typical of events involving chemical exposure or biological agents, public health agencies serve in a joint or supporting role to the overall response; response activities are moderate in number; response systems involve atypical partners; number of persons exposed defines event severity; and information and incident management activities are considered most essential to the response. Models such as these could have implications for planning and exercising with partner agencies, particularly with respect to setting expectations and developing a mutual understanding about the roles and responsibilities of public health agencies in various situations, an issue that has repeatedly been recognized as an area for improvement [8, 32].

Strengths

Our study benefits from three major strengths, including active case finding, a broad definition of urgent events, and the use of interviews as a data collection method. Our recruitment methods were costly and took considerable effort. However, as a result, we were able to gain access to a number and diversity of urgent event cases that would not have otherwise been available. In fact, fewer than ten percent of the cases included in this investigation were published in the peer-reviewed literature or other professional information-sharing web portals, confirming our presupposition that the publicly available literature describes a very limited proportion of events experienced by LHDs. It may be worth noting that when we initially proposed this project, several practitioners and researchers advised the use of the Department of Homeland Security's Lesson Learned and Information Sharing (LLIS) web portal, which they believed contained a fairly comprehensive set of response summaries. Only two percent of our cases indicated that resulted in the submission of a summary report to this database. Another strength of this study is the adoption of a broad definition of urgent events, thereby greatly expanding the available case material on public health responses. By pooling data across cases with different contexts, we had a sufficient sample size to examine patterns, highlight commonalities and differences across events with different contexts, and generate hypotheses for future study. Third, because this is a fairly new field of research, the use of interviews for data collection was invaluable, as this method provided respondents the opportunity to ask for clarification on questions and for interviewers to ask follow-up questions and to hear how health department representatives describe their response. These qualitative data, while not highlighted in our findings, greatly influenced the insights we drew from the data. This study was also strengthened by the availability of organizational data, provided by 2010 Profile of LHDs, which provided a sampling frame of local health departments, allowing us to better understand the representativeness of our sample and interpret our findings, and affording us the opportunity to examine how characteristics of a health department influence our outcomes of interest [21]. Finally, our approach also draws strength from the application of a systems-based and functions-based approach, both seen as essential features of high-quality research in this field [8]. By using the CDC Public Health Preparedness capabilities as a framework for conceptualizing public health activities, we hope to be able to contribute to the scientific literature in a way that is standardized, and thus allows for comparison with future research.

Limitations and Next Steps

While our results describe the responses to a wide range of incidents, our findings do not draw from a sample that is representative of health departments or urgent public health incidents across the United States. Representativeness was not a cornerstone of our sampling goal; however, in order to appropriately interpret the findings of this study, we believe that it is important to recognize the ways in which our findings are not representative. First, while we were able to achieve the desired number of cases for comparison, we had a fairly low overall response rate (35%). Based on the reasons for not participating provided by a subset of our non-respondents, a significant proportion of health departments in this group may not have experienced an incident that met study criteria. Therefore, we believe that the true response rate of *eligible* LHDs was considerably higher. Nonetheless, we recognize that respondents systematically differed from non-respondents: they were significantly more likely to serve a larger population, have higher public health expenditures per capita, and have more full-time staff. Non-respondent health departments' capacity or inclination to participate may be related to a specific response profile that is underrepresented in our results. Second, we allowed respondents to select a single event, which is one of many from which they could have potentially chosen. We do not claim to know anything about the events that were not selected; therefore, it is not possible to know how representative our set of events really is. We do know that the distribution of event types in our sample is similar to that found in other research. However, information is at the event type level (e.g. severe weather), and this may mask important details regarding the frequency of specific events that would be important for a more complete understanding of representativeness (e.g. a health department may have noted that they experienced an infectious disease event and a chemical event, when in reality they experienced ten infectious disease outbreaks and one chemical event) [21]. Furthermore, certain types of events occur more frequently in our dataset, such as norovirus outbreaks and hurricanes. As a result, each event profile is more greatly influenced by these more frequent events. Last, health departments that served a population of fewer than 50,000 individuals were excluded from our sampling strategy. The response system attributes of these health departments, which often have very limited staffing, warrant additional study.

A second limitation of this investigation is that our results tell us only whether certain activities were initiated and partners were involved in a response. We did not attempt to characterize the quality or appropriateness of those partners or activities, given the context of a particular event. Additionally, we do not provide information on the organizational, inter-personal, leadership, training, and historical factors that likely influenced whether responding agencies considered response measures to be appropriate and actionable. We stripped cases of this context, not because we believe context does not matter. Far from it. We believe that a careful examination of these contextual factors, using the right case material, could be exactly what is needed to elucidate mechanisms for improving the delivery of public health services during acute events. However, we think it is equally valuable, particularly at this stage, to describe the landscape of urgent events in a way that might help other researchers ask better and more informed questions. Furthermore, in the absence of validated performance measures, we were unable to link these data to meaningful outcomes.

As an extension of this work, we recommend that future studies examine the types of events that were less commonly reported in our sample, including mass casualty and chemical events, and to build on the profiles that we have developed to-date. If these profiles prove to be useful to practitioners or researchers, it may be valuable to investigate mechanisms for ongoing data collection and dissemination. To further explore this idea, we have developed a collaboration with a research group that seeks to test the feasibility and utility of creating a "Critical Incident Registry," similar to one used by the airline industry as a tool for learnng from crashes and near-misses [Stoto et al, unpublished]. Last, with little previous research to rely on, we took a broad and inductive approach to learning about public health response systems. We hope that the findings from this research will serve as a catalyst for future research that help us to better understand, measure, and improve public response systems.

Conclusion

In this study, we collect highly structured data on more than 120 real-world acute public health incidents. This represents the broadest set, to date, of events that have stressed the public health system in the United States. As a result, we are able to make comparisons across events and to identify functional and structural response patterns that could have relevance to public health practitioners and researchers.

Tables and Figures

Figures

Figures can be found at the end of Chapter 3

Figure 1. Recruitment Flow Diagram

This flow diagram summarizes the sampling and recruitment steps that resulted in the study population of 123 local health departments. Reasons for non-participation are provided, where possible.

Figure 2. Geographic distribution of cases

This map shows the distribution of participating agencies across the United States. States with greater number of participating local health departments (LHDs) are shaded darker red. States with the greatest number of participating health departments included California (12 LHDs), Ohio (8 LHDs), North Carolina (8 LHDs), Texas (7 LHDs), Florida (7 LHDs), and New Jerseyy (7 LHDs). Image developed using Google Map data ©2013 Google, INEGI.

Figure 3. Response activity profiles, by event type

This figure shows the profile of response activities for each of six different types of events, displayed as separate bar charts. For a given event type, the blue vertical bars show the proportion of cases that involved each of the 19 defined response activities. The horizontal gray bars provide the percent of cases for which that activity was perceived to be "essential." For example, within infectious disease events (top box), 100% of cases involved epidemiology and surveillance (Activity A), and in 82% of cases this activity was felt to be essential. The activities are ordered by five functional domains: investigation, disease control and prevention, information and incident management, surge management, and community resilience.

Figure 4. Public health response system profiles, by event type

This figure shows the public health response system profile for each of six different types of events, displayed as separate bar charts. For a given event type, the green vertical bars show the proportion of cases that involved each of the 41 defined response partners. For example, within infectious disease events (top box), 98% of cases involved local public health agencies (Organization Type A). The types of organizations are ordered based on the overall frequency with which they were mentioned in all 123 cases, most frequent to least frequent, from left to right. A gray bar, at the 50% marker, is included in each bar chart to highlight those organizations involved in more than half of cases.

Tables

Table 1. Participating Local Health Departments and Respondent's Role

This table provides a descriptive summary of respondents including characteristics of the public health agency and agency representatives.

Continuous Variables	mean	median	min	max	Signif
Population size (in thousands), n=123	542	297	51	>2,000	*
Expenditures per capita, n=111	78	43	<10	>200	*
Number of Full Time Equivalent staff (FTE), n=113	333	122	10	>1000	*
Categorical Variables	n	% of Cases			
Governing authority					
Centralized authority at the state	18	15			
Decentralized, authority at the local level	84	69			
Shared or mixed	19	16			
Geographic area served by agency					
City	14	12			
City-county	2	2			
County	85	70			
Multi-city	3	2			
Multi-county	17	14			
Types of Services directly provided by agency					
Comprehensive primary care services	20	17			
Any environmental health services	105	85			
Position or title of respondent(s)[1]					NA
Preparedness and Response	78	63			
CD Staff/Epidemiologist	48	39			
Environmental Health	12	10			
Health Director/Deputy	13	11			
Health Officer/Deputy	7	6			
Other	25	20			

[1] Respondents could identify more than one position or title

Table 2. List of events

This table summarizes the total number of cases within each event category and provides the number of cases for each sub-category event (e.g. number of urgent event cases involving the disease pertussis).

Event Category	# of Case Reports	Event detail (# of case reports)
Infectious disease event	51	Norovirus (9), Pertussis (7), Salmonellosis (6), Shiga toxin-producing *Escherichia coli* (STEC) (4), Tuberculosis (3), Hepatitis A (2), Measles (2), Meningococcal disease (2), Mumps (2), *Bacillus cereus* (1), Botulism (1), Campylobacteriosis and Guillian Barre Syndrome (1), Coliform bacteria (1), Cryptosporidiosis (1), Cyclosporiasis (1), Hantavirus pulmonary syndrome (1), Legionellosis (1), Lyme disease (1), Novel influenza A virus infections (1), Rabies-Animal (1), Shigellosis (1), Unknown Etiologic Agent (1), Varicella (Chicken pox) (1)
Severe weather/Natural disaster	45	Hurricane/Tropical Storm (16), Severe winter weather (7), Tornado (7), Flooding (5), Fire (5), Severe rain or wind storm/derecho (5)
Chemical or drug event	10	Bath Salts/White Rush (1), Hydrogen Sulfide, Natural Gas, Mercaptans (1), Blueberry Spice (Designer Drug) (1), Diesel Fuel And Lubricating Oil (1), Hydrogen Sulfide/Methane Gas (1), Pulverized Limestone (1), Crude Oil, Tarballs (1), Isocyanate (1), Liquid Mercury (1), Lead, Arsenic (1)
Radiation event	4	Iodine-131, Cesium-134, Cesium-137 (3), Strontium-82 And Strontium-85 (1)
Mass casualty event	2	Explosion (1), Plane crash (1)
Technological emergency	2	Mechanical failure at water treatment plant (1), Transformer fire (1)
Anticipated event	2	Planned mass gathering (1), Displaced persons from natural disaster/severe weather (1)
Complex event	1	Displaced persons from natural disaster/severe weather & infectious disease outbreak (cholera) (1)
Total	123	

Table 3. Event Characteristics

This table summarizes key event characteristics, including: duration of response time, number of individuals contacted to investigate illness or injury, number of probable or confirmed cases, number of severe cases, and number of individuals who received prophylaxis.

Event Characteristics	# of case reports	mean	sd	min	median	max	Signif.
Duration of response (in days)	(123)	64	125	0.2	18	854	**
Number of individuals contacted to investigated illness or exposure	(96)	756	2,111	0	80	11,000	
Number of probable or confirmed cases	(90)	37	82	0	7	565	*
Number of severe cases (number of hospitalizations or deaths)	(106)	3	7	0	0	51	
Number of individuals who received prophylaxis	(27)	1,253	2,376	0	161	10,240	

*Differences between infectious disease and non-infectious disease events significant at $p < 0.05$
**Differences between infectious disease (excluding events involving a bioterrorism agent) and non-infectious disease events significant at $p < 0.05$

References

1. Roueché B: *The medical detectives*. Washington Square Press; 1982.

2. Gregg MB: *Field epidemiology*. Oxford University Press US; 2002.

3. Thacker SB, Buffington J: **Applied epidemiology for the 21st Century**. *INT J EPIDEM* 2001, **30**:320 –325.

4. U.S. Senate: **Pandemic and All-Hazards Preparedness Act. Report [to accompany S. 3678]**. 2006:109–319.

5. Hodge JG, Gostin LO, Vernick JS: **The Pandemic and All-Hazards Preparedness Act**. *JAMA* 2007, **297**:1708 –1711.

6. Nelson C, Lurie N, Wasserman J, Zakowski S: **Conceptualizing and Defining Public Health Emergency Preparedness**. *Am J Public Health* 2007, **97**:S9–S11.

7. Centers for Disease Control and Prevention: **Public Law 109-417, § 101 et seq. Pandemic and All-Hazards Preparedness Act (PAHPA)**. 2006.

8. Acosta J, Nelson C, Beckjord E, Shelton S, Murphy E, Leuschner KJ, Wasserman J: *A National Agenda for Public Health Systems Research on Emergency Preparedness*. RAND Corporation; 2009.

9. Asch SM, Stoto M, Mendes M, Valdez RB, Gallagher ME, Halverson P, Lurie N: **A review of instruments assessing public health preparedness.** *Public Health Rep* 2005, **120**:532–542.

10. Nelson C, Lurie N, Wasserman J: **Assessing Public Health Emergency Preparedness: Concepts, Tools, and Challenges**. *RAND Corporation* 2007.

11. Lurie N, Wasserman J, Nelson CD: **Public health preparedness: Evolution or revolution?** *Health Affair* 2006, **25**:935.

12. National Biodefense Science Board: *Call to Action: Include Scientific Investigations as an Integral Component of Disaster Planning and Response*. 2011.

13. Nelson CD, Willis HH, Chan EW, Shelton SR, Parker AM: **Federal Initiative Increases Community Preparedness For Public Health Emergencies**. *Health Affair* 2010, **29**:2286 –2293.

14. Savoia E, Agboola F, Biddinger PD: **Use of After Action Reports (AARs) to Promote Organizational and Systems Learning in Emergency Preparedness**. *Int J Environ Res Publ Health* 2012, **9**:2949–2963.

15. Donahue AK, Tuohy RV: **Lessons we don't learn: A study of the lessons of disasters, why we repeat them, and how we can learn them**. *Homeland Security Affairs* 2006, **2**:1–28.

16. Larson RC, Metzger MD, Cahn MF: **Responding to Emergencies: Lessons Learned and the Need for Analysis**. *Interfaces* 2006, **36**:486–501.

17. Mays GP, Scutchfield FD, Bhandari MW, Smith SA: **Understanding the Organization of Public Health Delivery Systems: An Empirical Typology**. *Milbank Q* 2010, **88**:81–111.

18. Mays GP, Halverson PK, Baker EL, Stevens R, Vann JJ: **Availability and Perceived Effectiveness of Public Health Activities in the Nation's Most Populous Communities**. *Am J Public Health* 2004, **94**:1019–1026.

19. Hunter JC, Yang JE, Petrie M, Aragón TJ: **Integrating a framework for conducting public health systems research into statewide operations-based exercises to improve emergency preparedness**. *BMC Public Health* 2012, **12**:680.

20. **CDC Emergency Preparedness & Response Site** [http://emergency.cdc.gov/].

21. National Association of County and City Health Officials (NACCHO): *National Profile of Local Health Departments*. 2010.

22. **HealthMap** [http://healthmap.org/en/].

23. U.S. Centers for Disease Control and Prevention (CDC): *Public Health Preparedness Capabilities: National Standards for State and Local Planning*. 2011.

24. Aragon T, Enanoria W, Reingold A: *Outbreak Investigation: Quick Reference Guide*. CIDER; 2009.

25. Reingold AL: **Outbreak investigations–a perspective.** *Emerging Infectious Diseases* 1998, **4**:21.

26. Mays GP, Smith SA, Ingram RC, Racster LJ, Lamberth CD, Lovely ES: **Public Health Delivery Systems: Evidence, Uncertainty, and Emerging Research Needs**. *Am J Prev Med* 2009, **36**:256–265.

27. Harris JK, Clements B: **Using social network analysis to understand Missouri's system of public health emergency planners**. *Public Health Rep* 2007, **122**:488–98.

28. Dato V, Wagner MM, Fapohunda A: **How outbreaks of infectious disease are detected: a review of surveillance systems and outbreaks.** *Public Health Rep* 2004, **119**:464–471.

29. U.S. Department of Health and Human Services (HHS): *National Health Security Strategy*. 2009.

30. *Research Priorities in Emergency Preparedness and Response for Public Health Systems: A Letter Report*. National Academy Press; 2008.

31. Biddinger PD, Cadigan RO, Auerbach BS, Burstein JL, Savoia E, Stoto MA, Koh HK: **On Linkages: Using Exercises to Identify Systems-Level Preparedness Challenges**. *Public Health Rep* 2008, **123**:96–101.

32. Stoto MA, Dausey DJ, Davis LM, Leuschner K, Lurie N, Myers S, Olmsted S, Ricci K, Ridgely MS, Sloss EM, others: **Learning from experience: the public health response to West Nile virus, SARS, monkeypox, and hepatitis A outbreaks in the United States**. *RAND Corporation* 2005.

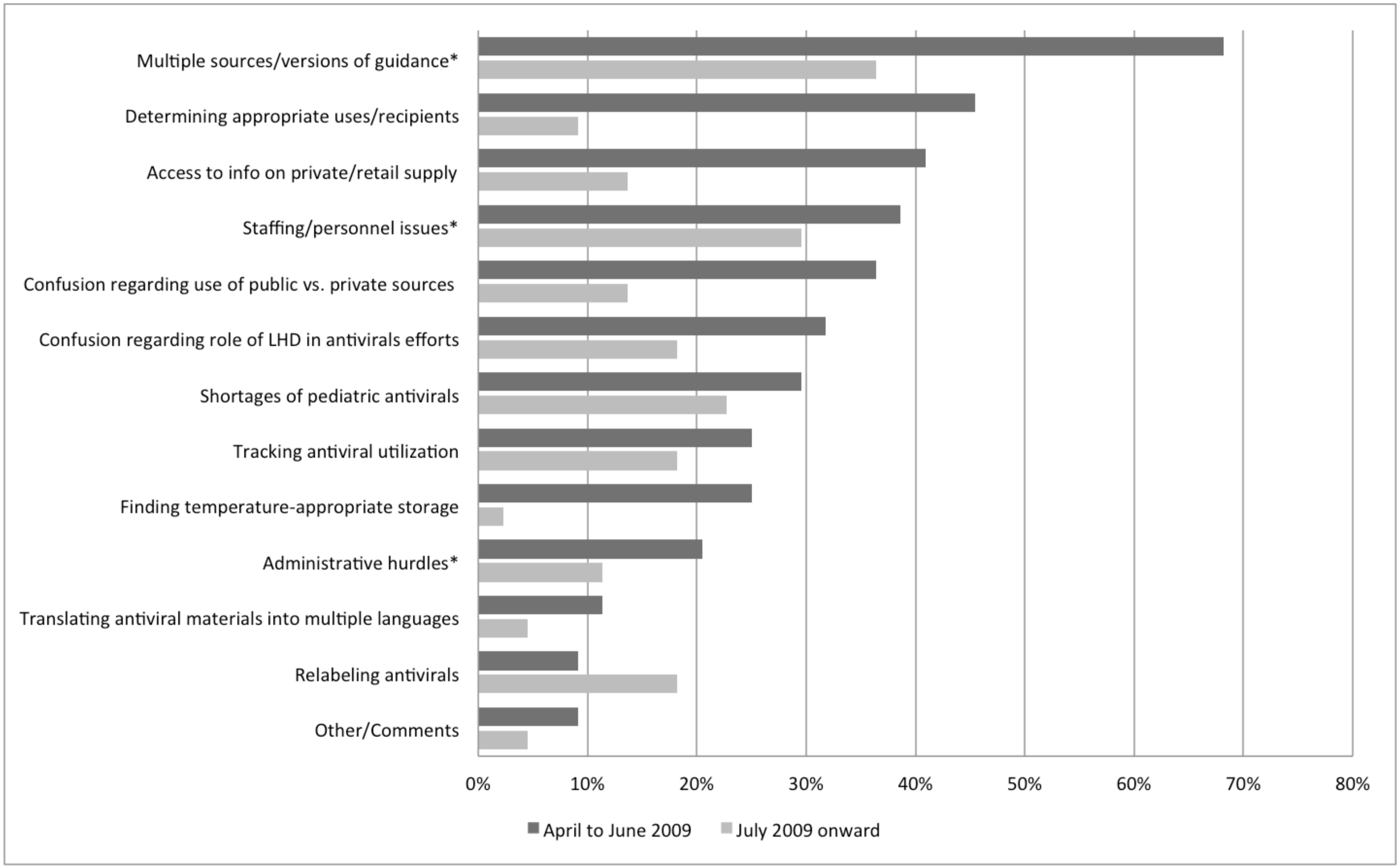
33. Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ: **Practical challenges of systems thinking and modeling in public health**. *Am J Public Health* 2006, **96**:538.

34. Leischow SJ: **Systems Thinking and Modeling for Public Health Practice**. *Am J Public Health* 2006, **96**:403–405.

35. Bovaird T: **Emergent Strategic Management and Planning Mechanisms in Complex Adaptive Systems**. *Public Manag Rev* 2008, **10**:319–340.

36. Thompson JD, Zald MN, Scott WR: *Organizations in action: Social science bases of administrative theory*. Transaction Pub; 2003.

Figure 1. Antiviral challenges reported by Local Health Departments, by time period (n=44)



Chapter 5: Concluding Remarks

The most powerful motivation guiding this project was a strong belief, rooted in years of practical experience, that despite modest successes and widely recognized challenges in public health preparedness research, it was and is possible to develop a stronger understanding of the nature of public health response operations. This belief, coupled with another, that an evidence base built from the rich experiences of many practitioners would provide the best insights for guiding, measuring, and improving the future public health response system, led me to three years of research – in the field, on the phone, through the web – that ultimately characterized the details of more 250 urgent public health cases; the most that any systematic comparison has ever captured. Through this research, I have learned much. I am indebted to those practitioners who were willing to share their experiences responding to incidents, which ranged from the unusual, to the mysterious, to the devastating. One incident at a time, these narratives provided an unparalleled education on the public health response system in action. In the following pages, I provide a few concluding remarks, which summarize a small part of I was able to learn through this process. In the first section, I reflect on the problem of learning from the perspective of a single local health department and briefly highlight a few findings from the previous chapters as a way to demonstrate the nature of insights that are possible through research of this kind. The second section concludes with policy implications, particularly with respect to future guidance and accountability efforts.

<u>First, on learning opportunities for local public health agencies</u>

Local public health agencies are faced with extraordinarily restricted opportunities for learning from real-world urgent events. One reason is the infrequency with which these events occur for any given community. More than half of the health departments that we surveyed (Chapter 3) described an event that happens every few years or an event that was the only one of its kind in recent history. A second reason is access to others' experiences. Only a small fraction of urgent public health incidents are summarized and disseminated to the outside world, likely due to a range of factors including time constraints and concerns over legal or political repercussions. Moreover, when incident summaries are actually shared, reports are so varied in structure and level of completeness that making comparisons across events and drawing parallels to one's own experiences is very challenging [1]. Opportunities for experiencing or learning from events other health departments face are further constrained by budget cuts, travel restrictions, and a general funding environment that makes it difficult to justify activities that do not meet specific grant requirements [2]. As a consequence, for many types of events, health departments are limited in their own direct experiences and have almost no access to descriptions of the experiences of others. This environment stands in stark contrast to other organizations that are expected to perform reliably in high stress environments, such aircraft carriers, where extensive field experience results in finely tuned expectations for behavior, or air traffic systems, where the study and dissemination of lessons learned from near-miss incidents serves as a cornerstone for learning and improvement [3, 4].

Above all, this research demonstrates that it is possible to identify meaningful insights from a large set of real world events – insights that might not be evident from an examination of single isolated incidents – and that these lessons may have relevance in other public health settings and contexts. This may be, in fact, the most important finding. A few themes regarding the potential for practical relevance of these findings, developed in prior chapters, include:

Different hazards elicit particular response patterns. The findings from Chapters 2 and 3 demonstrate that the functional and structural character of the public health response system changes, sometimes quite dramatically, based on the characteristics of the event stressing the community. In other terms, the nature of the perturbation on the system results in various organizational forms, often quite different from one another. The resulting response profiles, particularly those displayed in Chapter 3, suggest the existence, perhaps, of a few predictable configurations common to public health response efforts. For example, in one model, most typical of severe weather and natural disasters, public health agencies serve in a joint or supporting role to the overall response, the response activities and partners are more numerous and diverse, disruption to community infrastructure defines event severity, and environmental health and mass sheltering and care activities are considered most essential to the response. A model such as this could provide a new approach to planning that builds on the strengths those currently used. Like planning based on single scenarios (e.g. aerosolized anthrax), this type of model is grounded in concrete real-world cases, making it easier to conceptualize the likely functional and structural aspects of a response. This allows for the development of detailed response protocols, which can be used to guide the training of staff and purchase of resources needed to test, implement, and improve these plans. At the same time, this model is general enough that insights and skills gained from planning for one threat can be expected to be applicable, although not identical, to another hazards with a similar profile, increasing the efficiency of planning.

Public health response capabilities: Some common, others not. In Chapter 3, we identify substantial variation in the frequency with which each type of response function was required. This finding may suggest different approaches for staffing, training, and organizing, based on the regularity with which capabilities are expected. One end of the spectrum, we see a "core set" of public health response capabilities, which are activated almost universally, regardless of the event context. Given their frequency, these capabilities may be considered as targets for intensive training, simulation, and assessment. Through these efforts, the public health professionals responsible for core functions may be able to develop highly programmed and efficient response structures, even if the other necessary components of a particular response are more difficult to anticipate. On the other end of the spectrum, our findings also suggest that certain capabilities, such as fatality management, are only prompted under rare and hazardous situations. Given the infrequent opportunity for learning within a given community, this raises the question of whether it is realistic and prudent for an individual health department to invest the resources needed to obtain and retain this technical capacity. An alternate organizational configuration, perhaps more appropriate for these uncommon but critical capabilities might be the development of regional rapid response teams, which are staffed by personnel experienced in a particular or set of uncommonly tested capabilities who regularly train with health departments in their region to develop trust and mutual understanding of operating within each organizational and political environment.

Current formulations of public health response capabilities can be improved. The CDC's capabilities-based planning model rests on a rational assumption that preparedness can be achieved by directing resources towards building, testing, and improving a defined set of expected response functions. Our findings reinforce the benefit of the current direction of this preparedness policy and also suggest that future guidance could be improved by further specifying, using real-world experiences, the circumstances in which capabilities are expected to have relevance. For example, providing the types of hazards that commonly require certain sets of capabilities and the frequency with which community partners contribute to response functions could serve to improve preparedness directors' expectations of the likely functional and structural aspects of hazards that are rarely experienced in their community. Additionally, in-depth analyses of incidents that simultaneously affected many communities offer an opportunity for policy makers to present on the range of implementation practices observed for a particular capability (as described for antiviral management during the 2009 H1N1 influenza pandemic, **Chapter 4**). Recognition of variations in practice, along with expert analysis of which variations are seen as beneficial and adaptive versus those that could benefit from uniformity, may be particularly informative for improving future expectations and could further preparedness and response dialogue.

During the course of our studies, we noted many response activities that were identified by participating agencies but that were underspecified or missing from the current formulation of the PHEP Capabilities. If the incomplete nature of this guidance is not fully appreciated by the agencies that are expected to implement it, there is a threat that health departments may develop a false (and inflated) impression of their own preparedness. It is, therefore, tempting to propose adding an even greater number of capabilities to the CDC framework to make it "complete." Alternately, this finding could indicate that it is not possible to anticipate all of the potential response functions, and that a complimentary planning model is thus needed. For example, models of organization and planning that emphasize the skills an training required for public health leaders to organize "on-the-fly" may further equip public health leaders with the necessary tools to manage the unpredictable health functions required during many urgent events [5].

<u>Second, on measurement and accountability</u>

Given the current political environment, which increasingly demands accountability from the public sector, our findings may prove to be particularly informative. In the absence of strong empirical evidence, policy makers have relied on expert opinion and a very limited research base to guide the development of standards, guidance, and performance measures

[6]. Our research demonstrates that the available literature is far from representative of the urgent events that health departments face, with a bias in favor of infectious disease events, and that the available descriptions of the public heath system in-action are far too simplified. In relying on this limited evidence base, it seems likely that policies will be based on assumptions and expectations of the public health system that are distant from reality. The result may not just be a waste of health departments' and responders' limited time and resources, but may also lead to a false sense of preparedness, and an increasing pessimism about the merits of learning, measurement, and improvement efforts. If this is true, holding public health systems accountable to policies that are based on incomplete and oversimplified conceptions of their operations may present a liability to preparedness.

Continued and rigorous examination of the experiences of health departments throughout the nation will refine our very understanding of what the public health response system is, in practice, will enable the identification of organizational and event inputs to performance, and will allow for the construction of an ever more rich, relevant, and practical models of response operations that might then be employed to strengthen public health systems. This project has demonstrated that this type of research is feasible. Specifically, the research team included only three primary actors – myself (a doctoral candidate); a really great research assistant; and a visionary mentor. Now is the time to move the public health preparedness system, including policy makers, beyond the status quo, where it is acceptable that "performance measures and standards, best practices, program guidance, training, and other tools have proceeded without a strong empirical and analytical basis" [6]. Future policy and practice must be based on the very best evidence.

References

1. Savoia E, Agboola F, Biddinger PD: **Use of After Action Reports (AARs) to Promote Organizational and Systems Learning in Emergency Preparedness**. *Int J Environ Res Publ Health* 2012, **9**:2949–2963.

2. National Association of County and City Health Officials (NACCHO): *LHD Budget Cuts and Job Losses*. 2012.

3. Rochlin GI, LaPorte TR, Roberts KH: *The Self-Designing High-Reliability Organization: Aircraft Carrier Flight Operations at Sea*. Naval War College Review; 1987.

4. March JG, Sproull LS, Tamuz M: **Learning from samples of one or fewer**. *Organ Sci* 1991, **2**:1–13.

5. Mintzberg H: **The pitfalls of strategic planning**. *California Management Review* 1993, **36**:32–32.

6. Acosta J, Nelson C, Beckjord E, Shelton S, Murphy E, Leuschner KJ, Wasserman J: *A National Agenda for Public Health Systems Research on Emergency Preparedness*. RAND Corporation; 2009.

APPENDIXES

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Appendix A: Data abstraction tool for structured literature review

MMWR – Data Abstraction tool

Article Details

Article ID (1)
Last name of first author (2)
Publication year (3)
Journal Name (4)

If applicable, state reason article was excluded:

- ❑ Article included - Not applicable (9)
- ❑ Focuses on clinical response only (1)
- ❑ Public health response not described in enough detail (2)
- ❑ Focuses on limited aspects of a response (3)
- ❑ No state or local public health involvement (5)
- ❑ Federal investigation (e.g. retrospective investigation of exposures) (4)
- ❑ Describes surveillance and disease or exposure trends only (6)
- ❑ Describes multiple unrelated cases, each with not enough detail (7)
- ❑ 2009-10 H1N1 Influenza (18)
- ❑ Other (8) ____________________

How many LHDs and/or states were involved in this event response?

- ❍ Only one LHD (1)
- ❍ More than one LHD in the same state (2)
- ❍ More than one LHD in multiple states (3)
- ❍ Don't know (4)

Where did this event take place? If multiple LHD and/or states, enter each health department.

Does this MMWR describe...

- ❍ A response initiated at the local level (1)
- ❍ A response initiated at the state level (2)
- ❍ A response initiated at the federal level (3)
- ❍ An assessment or investigation initiated at the local, state, or federal level - not in response to an acute event (4)
- ❍ Other (5) ____________________
- ❍ DK/Unable to answer (6)

Approximately, when did the event begin? (If unknown, write "DK")

Month event began (mm) (1)
Year event began (yyyy) (2)

Which general category best describes this event?

- ❍ Infectious disease outbreak (1)
- ❍ Severe weather / Natural disaster (2)
- ❍ Chemical exposure (3)
- ❍ Radiation event (4)
- ❍ Bioterrorism event (suspected or confirmed) (5)
- ❍ Mass casualty event (6)
- ❍ Other (Please describe) (8) ____________________

What agent was responsible for this outbreak? (Please be as specific as possible, if unknown please enter "Unknown")

Please categorize this infectious disease agent by mode of transmission:

- ❍ Food-borne (1)
- ❍ Water-borne (2)
- ❍ Vector-borne (3)
- ❍ Airborne/Droplet (4)
- ❍ Vertical transmission (5)
- ❍ Human contact (Direct/indirect) (6)
- ❍ Animal contact (Direct/indirect) (7)
- ❍ Other vehicle-borne (8)
- ❍ Unknown transmission (9)
- ❍ Other (Please describe) (10) ____________________

Please indicate the type of natural disaster:

- ❍ Flooding (1)
- ❍ Severe winter weather (2)
- ❍ Severe summer weather (3)
- ❍ Fires (4)
- ❍ Hurricane (5)
- ❍ Tornado (6)
- ❍ Tsunami (7)
- ❍ Earthquake (8)
- ❍ Other (Please describe) (9) ____________________

What type of chemical(s) was involved in this event?Please be as specific as possible (e.g. Toluene)

What was the source of the chemical exposure?Please be as specific as possible (e.g. agricultural spill, oil spill)

Which of the following were suspected/confirmed sources of contamination following the chemical exposure?

- ❑ Humans (1)
- ❑ Animals (2)
- ❑ Food (3)
- ❑ Water (4)
- ❑ Soil (5)
- ❑ Air (6)
- ❑ Other (Please describe) (7) ____________________

What was the source of the radiation event? Please be as specific as possible.

Which of the following were suspected/confirmed sources of contamination following the radiation event?

- ❑ Humans (1)
- ❑ Animals (2)
- ❑ Food (3)
- ❑ Water (4)
- ❑ Soil (5)
- ❑ Air (6)
- ❑ Other (Please describe) (7) ____________________

What was the cause of the mass casualty event?Please be as specific as possible (e.g. explosion, bridge collapse).

Which of the following were suspected/confirmed sources of contamination following the bioterrorism event?

- ❑ Humans (1)
- ❑ Animals (2)
- ❑ Food (3)
- ❑ Water (4)
- ❑ Soil (5)
- ❑ Air (6)
- ❑ Other (Please describe) (7) ____________________

What was the cause of this event? Please be as specific as possible (e.g. specific agent).

The following questions ask about the size and severity of the event. Please indicate the estimated number of...

Cases screened or investigated (3)
Confirmed or probable cases (illness or injury) (2)
Severe cases (hospitalized and deaths) (5)
Individuals who received PEP/PrEP (4)
Deaths (6)

If there are other indicators of event severity that are not listed above, please describe here:

Were there any public health, environmental health, or medical services disrupted as a result of this event?

- ❑ No services disrupted (1)
- ❑ Water services (2)
- ❑ Sewage services (3)
- ❑ Power/electricity (4)
- ❑ Roads/transportation (5)
- ❑ Other public health services (6)
- ❑ Medical services (7)
- ❑ Other (8) ____________________
- ❑ Don't know/unable to answer (9)

What types of settings were most affected during this event

- ❑ Individuals/households (1)
- ❑ Congregate housing facilities (2)
- ❑ Educational facilities (3)
- ❑ Healthcare facilities (4)
- ❑ Recreational facilities (5)
- ❑ Restaurants/Grocery Stores (6)
- ❑ No specific settings (7)
- ❑ Other (8) ____________________
- ❑ Don't know/Unable to answer (9)

What geographic area was affected by the event?

- ❍ Very localized (e.g. among attendees of an event) (1)
- ❍ Very localized but with wider geographic scope (2)
- ❍ Local (3)
- ❍ Regional (4)
- ❍ Widespread (5)
- ❍ Unknown (6)

What population(s) were most affected by this event? (Check all that apply)

- ❑ Occupational populations (e.g., health care workers, those who work outdoors) (1)
- ❑ Pregnant women (2)
- ❑ Infants (0-3 years) (3)
- ❑ Children/Adolescents (3-18 years) (4)
- ❑ Senior citizens (5)
- ❑ Low income individuals (6)
- ❑ Persons with chronic medical conditions (7)
- ❑ Rural or geographically isolated individuals (8)
- ❑ Transient populations (e.g. homeless, migrant workers, tourists) limited English proficiency (9)
- ❑ Persons functionally at-risk for Communication (e.g. hearing, vision, speech, limited English proficiency) (10)
- ❑ Persons functionally at-risk for Transportation (e.g. persons who cannot drive or who have limited access to a car) (11)
- ❑ Persons functionally at-risk for Medical Care (e.g. persons who are not self-sufficient or who do not have adequate support from caregivers, family (12)
- ❑ Persons functionally at-risk for independence or supervision (e.g. persons requiring support/supervision to be independent or who may not be able to cope in new environment; closed populations such as long-term care residents and prisoners) (13)
- ❑ General population was equally affected (14)
- ❑ Not specified (16)
- ❑ Other (Please describe) (15) ____________________

From whom did the LHD first learn about this event?

- ❍ Routine surveillance system (1)
- ❍ Notification by hospital or healthcare system (2)
- ❍ Notification by clinician (3)
- ❍ Notification by other LHD (4)
- ❍ Notification by state or federal health department (5)
- ❍ Notification by individual in the community (i.e concerned citizen) (6)
- ❍ Notification by school or university (7)
- ❍ Not specified (9)
- ❍ Other (Please describe) (8) ____________________

At the point when the LHD became involved, was the etiologic agent known?

- Yes (1) ____________________
- Somewhat (e.g. etiologic agent highly suspected, but not yet confirmed) (2)
- No (3)
- Not Applicable (4) ____________________
- Unknown (5)

At the point when the LHD became involved, was the source known?

- Yes (1)
- Somewhat (e.g. source of illness isolated to dinner, but implicated item not identified) (2)
- No (3)
- Not applicable (4) ____________________
- Unknown (5)

Was the sources of the outbreak determined at any point?

- Yes (1) ____________________
- No (2)
- Don't know/Unable to answer (3)

At the point when the LHD became involved, was the exposure/hazard ongoing?

- Yes (1)
- No (2)
- Not applicable (3) ____________________
- Unknown (4)

Which of the following PHEP activities were initiated in response to this event, regardless of whether they were carried out by the LHD? (Check all that apply)

- ❑ (SEI) Public health surveillance and epidemiologic investigations (13)
- ❑ (CHA) Community Assessment of health or needs (19)
- ❑ (RCA) Assessment of public health or medical response capacity (20)
- ❑ (ENV) Environmental or product investigation (16)
- ❑ (LAB) Public health laboratory testing (12)
- ❑ (SME) Consulting subject matter experts (21)
- ❑ (INFO) Information sharing (6)
- ❑ (PIG) Emergency public information and warning (4)
- ❑ (MED) Medical countermeasure dispensing (8)
- ❑ (NPI) Non-pharmaceutical interventions (11)
- ❑ (MMM) Medical material management and distribution (9)
- ❑ (MCS) Mass care (7)
- ❑ (RSH) Responder safety and health (14)
- ❑ (SURGE) Medical surge (10)
- ❑ (FAM) Fatality management (5)
- ❑ (VOM) Volunteer management (15)
- ❑ (COR) Community recovery (2)
- ❑ Community preparedness (1)
- ❑ Emergency operations coordination (3)
- ❑ None of the above (17)
- ❑ Unable to answer (18)

Did the health department rely on the potential cases or family members for information regarding exposure or illness?

- ❍ No (1)
- ❍ Yes (2)
- ❍ Don't know/Unable to answer (3)

Please describe public health activities not identified in PHEP capabilities list, above.

Which of the following were core response activities (i.e. those that required the greatest level of effort or were described in the greatest level of detail)?

Which of the following non-pharmaceutical interventions were implemented or recommended?

- ❑ Isolation/Quarantine (Human) (1)
- ❑ Isolation/Quarantine (Animal) (2)
- ❑ Screening (3)
- ❑ Restrictions on movement/travel advisories (4)
- ❑ Product advisory or recall (5)
- ❑ Establishment advisory or closure (6)
- ❑ Exclude persons from activities (e.g. food handlers from work) (7)
- ❑ Environmental or product decontamination (8)
- ❑ Environmental or ecological interventions (e.g. insecticide spraying) (9)
- ❑ Engineering controls (10)
- ❑ Recommendations for personal protective behaviors (e.g. social distancing, hand washing) (11)
- ❑ Euthanize animals (12)
- ❑ Other (13) ____________________

Which of the following medical countermeasures were utilized as part of the public health response (i.e. not as a part of standard clinical care)?

- ❑ PEP/PrEP (1)
- ❑ Treatment (2)
- ❑ Other (3) ____________________

Which of the following epidemiologic or surveillance activities were conducted?

- ❑ Case/contact finding and investigation (1)
- ❑ Cause investigation (interpret results of epi, lab, clinical, environmental, etc.) (2)
- ❑ Use epi/surveillance data to recommend control measures (3)
- ❑ Use epi/surveillance data to identify individuals/populations at-risk (4)
- ❑ Conduct analytic study (case/control or cohort study) (5)
- ❑ Other (6) ____________________

[Loop and merge for each activated PHEP Capability]

Which organizations/agencies contributed to ${lm://Field/1} activities?

- ❑ 1. Local Public Health (1)
- ❑ 2. Local Public Health Other (37)
- ❑ 3. State Public Health (2)
- ❑ 4. Federal Public Health (3)
- ❑ 5. Emergency management (6)
- ❑ 6. Emergency medical services (EMS) (5)
- ❑ 7. Law Enforcement (12)
- ❑ 8. Fire (13)
- ❑ 9. Public Works (14)
- ❑ 10. Transportation (16)
- ❑ 11. Occupational safety & health (9)
- ❑ 12. Food and agriculture/animal health (11)
- ❑ 13. Environmental Protections (18)
- ❑ 14. Military/Intelligence support (20)
- ❑ 15. Social welfare/Social services (10)
- ❑ 16. Medical examiner/coroner (21)
- ❑ 17. Tribal entities (22)
- ❑ 18. Political or Public Administration Office (38)
- ❑ 19. Healthcare providers/delivery systems (e.g. hospitals, skilled nursing facilities) (24)
- ❑ 20. (PHARM) Pharmacies and/or pharmacy associations (25)
- ❑ 21. (DRUG) Pharmaceutical/drug administration (8)
- ❑ 22. Commercial or clinical laboratories (26)
- ❑ 23. Health insurers (28)
- ❑ 24. Veterinary or animal health entities (27)
- ❑ 25. Other community or faith based organizations (31)
- ❑ 26. Red Cross (39)
- ❑ 27. Critical Infrastructure (gov't) (17)
- ❑ 28. Education (19)
- ❑ 29. Universities/Academia (29)
- ❑ 30. Legal Support (15)
- ❑ 31. Media (30)
- ❑ 32. Public (53)
- ❑ Other business (33)
- ❑ Other (Please describe) (34) ____________________
- ❑ No agencies contributed to these activities (35)
- ❑ Don't know/Unable to answer (36)

What was the duration of the LHD involvement in the response to this event? Please enter either the start and end date OR the approximate length of time (in days, weeks, or months).

Approximate start date (mm/dd/yyyy) (1)
Approximate end date (mm/dd/yyyy) (2)
Length of time (in days, weeks, or months) (3)

Did public health play a lead role, supporting role, or joint-effort?

- ❍ Supporting Role (1)
- ❍ Joint role (2)
- ❍ Leading role (3)
- ❍ Don't know/Unable to answer (4)

Additional Comments

What were the stated objectives of the public health response to this event? (Check all that apply)

- ❑ To identify additional cases (1)
- ❑ To identify a source/vehicle of infection that can be controlled/eliminated (2)
- ❑ To learn more about the natural history of a disease (3)
- ❑ To learn more about the clinical disease (4)
- ❑ To learn more about the descriptive epidemiology of a disease (5)
- ❑ To learn about possible new risk factors (6)
- ❑ To implement control measures (7)
- ❑ Evaluate prevention and control strategies (8)
- ❑ Teach epidemioloty (9)
- ❑ Address public concern (10)
- ❑ Other (Please describe) (11) ____________________

Comments

Does this event involve an novel, emerging, or re-emerging disease?

- ❍ Novel/emerging disease (1)
- ❍ Re-emerging disease (2)
- ❍ No (3)
- ❍ Don't know (4)

Did any of the following factors contribute to this event? (Select all that apply)

- ❑ Microbial adaptation and change (1)
- ❑ Human susceptibility to infection (2)
- ❑ Climate and weather (3)
- ❑ Changing ecosystems (4)
- ❑ Human demographics and behavior (5)
- ❑ Economic development and land use (6)
- ❑ International travel and commerce (7)
- ❑ Technology and industry (8)
- ❑ Breakdown of public health measures (9)
- ❑ Poverty and social inequality (10)
- ❑ War and famine (11)
- ❑ Lack of political will (12)
- ❑ Intent to harm (13)
- ❑ None of the above (14)

Comment

Did under-vaccination contribute to this event?

- ❍ Yes (1)
- ❍ No (2)
- ❍ Unknown (3) ____________________

Did this event result in regulatory or law enforcement action?

- ❍ Yes (1)
- ❍ No (2)
- ❍ Unknown (3) ____________________

Did this event involve a zoonotic disease?

- ❍ Yes (1)
- ❍ No (2)
- ❍ Unknown (3) ____________________

Recommendations

Final Comments

Appendix B: Organization categorization summary

CATEGORY	INCLUDES THE FOLLOWING…
EDUCATION (K-12/PRE-SCHOOL)	Education (pre-school, K-12)
	Dept. of Early Learning
PORTS OF ENTRY/TRAVEL	Quarantine station
	U.S. Customs/Immigration
FIRST RESPONDERS	Emergency Medical Services (State, local)
	Hazardous Materials
	Regional Fire Investigation and Hazardous Materials Response Team
	Fire Department (State, local)
	Search and Rescue
POISON CONTROL	Poison control
INTERNATIONAL GOV. AGENCY	International Public Health Agency
	Coast Guard (of another country)
OTHER REGULATORY AGENCY	Mental Health Authority
UNIVERSITY/ACADEMIC INSTITUTION	Universities/Academia
(SOCIAL WELFARE, MENTAL HEALTH)	Social welfare/Social services
	Disability Services
	Group homes (behavioral)
	Interpreter Services
	Behavioral health: Gov.
	Behavioral health: Non-Gov.
	United Way's 2-1-1 system
	Office serving vulnerable populations
	Aging section (within LHD)
	Aging agency/council (county)
	Emergency Support Function (#6: Mass Care, Emergency Assistance, Housing and Human
LAW ENFORCEMENT/PUBLIC SAFETY	Law Enforcement (State, local)
	Dept. of Public Safety
	Federal Bureau of Investigation
	Highway patrol
	Corrections facilities
	9-1-1 Call Center
	Dept. of Homeland Security (excluding FEMA)
NOAA	National Weather Service/NOAA
PRIVATE)	Health or other insurers
	County finance/Auditor's office
	Medicare and Medicaid
GENERAL PUBLIC	General public, includes: affected persons, family members, community members
PROFESSIONAL/TRADE ASSOCIATIONS	Professional organization for physicians
GOV.)	IT/Technology Sector
	Office of Drinking Water
	Building Department
	Critical Infrastructure: Non-Gov. (e.g. utilities, banks, transportation)
	Public works/utilities (State, local, non-Gov.)
	Transportation
	Engineer (public sector)
	National Traffic Safety Board
MEDIA	Media (e.g. private, public broadcasting)
	Radio communications technician/advisor
LEGAL SUPPORT	Legal Support
POLITICAL/PUBLIC ADMIN OFFICE	Political/Public Administration Office (e.g. city council, mayor, governor)
	Municipal administration
	Neighborhood and Constituent Services (cabinet-level dept.)
EXPERT CONSULTANT	GIS Advisor
	Subject Matter Experts on TB
	Property Appraisers office
EMERGENCY MANAGEMENT	Emergency Management/Office of Emergency Services (State, local)
	Disaster recovery emergency operations center
	State emergency operations center
DISASTER RELIEF	Military, National Guard, Army Corps of Engineers, Army Reserve
	Medical Response Systems
	Federal Emergency Management Agency
	Disaster Medical Assistance Team
ANIMAL/VET	Veterinary, animal health entities, or animal control (Gov., Non-Gov.)
PUBLIC INFORMATION	Office of Public Information
	Joint Information Center

	Public Information Officer
LOCAL PUBLIC HEALTH/ENV HEALTH	Local Public Health Dept. (self)[2]
	Another Local Public Health Dept[2]
	Environmental Health Department (separate from the local health dept.)
	Public health Field Strike Team
	Public health inspector
	Emergency Support Function (#8: Public Health and Medical Services) Desk at EOC
HEALTHCARE PROVIDERS	Hospital/Healthcare (e.g. private providers, clinics, long-term care facilities, hospitals)
	Contracted nurses for immunization services
	Sentinel surveillance physicians in community
FBO, ETC.)	Other community, faith-based, or volunteer organizations (e.g. MRCs, CERTs, Salvation Army)
	Emergency Function (#15: Volunteer Management)
LABS	Commercial or clinical laboratories
AD-HOC DISASTER ASSISTANCE CENTERS	Disaster relief - family assistance center
	Disaster relief shelter
	Disaster recovery center for affected community members
STATE PUBLIC HEALTH AGENCY	State Public Health Department
	Occupational Safety & Health
	LTCF Regulatory Agency
	Another State Public Health Department
	State Epidemiologist
FEDERAL PUBLIC HEALTH AGENCY	UC Centers for Disease Control and Prevention (all centers)
	CDC Epidemic Intelligence Service Officer
	US Public Health Service
FOOD AND AGRICULTURE	Food and Agriculture/Animal Health (e.g. FDA-food)
	Dept. of Agriculture
	County Extension Office
REGIONAL HEALTH & MEDICAL	
	Regional Emergency Preparedness Planner
	Regional Medical Operations Center
	Regional hospital coordinator
	Regional TB Manager
	Regional Epidemiologist
	Regional medical and health resource center
PHARMACY/DRUGS	Pharmaceutical/Drug Administration (e.g. drug regulation arm of FDA)
	Pharmacies and/or pharmacy associations
ENVIRONMENTAL/NATURAL RESOURCES	Environmental Protections
	Fish and Game
	Department of Agriculture/Forest Service
	Dept. of Natural Resources
	Department of Parks and Recreation
	US Fish and Wildlife Service
	ESF (#10: Oil and Hazardous Materials Response)
EMPLOYER/PRIVATE BUSINESS	Product Manufacturer
	Private business (excluding implicated business)
	Camps (residential and/or recreational summer)
	Business implicated in product or environmental contamination or transmission of illness
	Private Clean-up company
SUBSIDIARY LHD	Municipal Health Departments
TRIBAL	Tribal entities
MEDICAL EXAMINER/CORONER	Medical examiner/coroner
RED CROSS	Red Cross
VECTOR CONTROL	Mosquito control
HOUSING	Dept. of Housing
	Health agency overseen by another health department identified as the "LHD" by NACCHO
COMMUNITY CENTER	Community center
	Church
ONE-TIME PARTICIPANTS	Library
	Workforce development
	Event organizers

[1]Entries marked in red font indicate categories defined at the beginning of data collection

[2]Local Health Department defined by 2010 NACCHO Profile of LHD

Appendix C: Structured interview tool

Note to Interviewer:

This cover page contains individually-identifiable information.

To ensure confidentiality is protected, please remove this cover page after the interview is completed. The cover page should then be stored in a secure location.

Identifier

1) Participant ID: ________________________________

2) Nacchoid: __________________________

3) Round: __________________________

Name

4) First Name: ____________________________________

5) Last Name: ____________________________________

Email address & Phone Number

6) Email: ____

7) Phone: ___________________________

I have that you are with the [LHD Name]__________ in [State] ________. Is this correct?

8) State***:*** *(Pre-fill, Confirm above)* ________________________

9) Name of Local Health Department? *(Pre-fill, confirm above)*

____

<table>
<tr>
<td>
Sm(all)-Hazards Preparedness Project:
2012 Telephone Interviews of LHDs
Revised: 12/7/2012

<u>Admin Team use only</u>
Data Entry #1
Date of entry: ____________
Data entry person’s initials: ________
Completed data entry? ☐ Yes

Data Entry #2
Date of entry: ____________
Data entry person’s initials: ________
Completed data entry? ☐ Yes
</td>
<td>
Round: ________________________

Participant ID: ________________________

Interviewer Initials: ________________

Date: ________________

Follow-up Interviewer: ________________

Date of Follow-up Interview: ______________
</td>
</tr>
</table>

Block 1: Basic LHD/Respondent Demographic Information

☐***<u>CONFIRM LHD & STATE ON FIRST PAGE</u>***

1) ***What is your position or title at your health department?*** *(Open-ended or pre-fill)*
   ☐Health Director/Deputy (1)
   ☐Health Officer/Deputy Health Officer (2)
   ☐Public health preparedness and response coordinator/director (3)
   ☐Other (4) ____

2) ***Are you affiliated with a specific branch in your health department****? (Open-ended or pre-fill)*
   ☐Communicable disease (1)
   ☐Public health preparedness and response (2)
   ☐Laboratory (3)
   ☐Environmental health (4)
   ☐Disease-specific branch (Circle: HIV/AIDS, TB, STD) (5)
   ☐Other (6) ____
   ☐No (e.g. Health Officer/Director (7)

I understand that we'll be talking about your experiences with the ______________________ [event]. *(OK to just confirm event type & specific agent here, if obvious, e.g. "an infectious disease event involving salmonella.")*

3) ***What was your position or title in the response to this specific _______ [event]?*** *(Open-ended, OK if responses don't match response options)*
   ☐Incident commander/manager (1)
   ☐Operations chief/deputy (2)
   ☐Planning chief/deputy (3)
   ☐Same as day-to-day role (4)
   ☐Other (5) ____

Block 2: Event Characteristics

4) ***Can you tell me approximately when the event began?*** *(Prompt to specify month and year, if not stated)*

   Month event began (mm) ________________
   Year event began (yyyy) _________________

   ☐Don't Know/Unable to answer

   ☐Event still ongoing

5) ***Would you categorize this as a ______________________ [event]?*** *(Pre-fill if possible and verify)*

   ☐Infectious disease outbreak/event (1)

   ☐Severe weather / Natural disaster (2)

   ☐Chemical exposure/contamination (3)

   ☐Radiation event (4)

   ☐Bioterrorism event (suspected or confirmed) (5)

   ☐Mass casualty event (6)

   ☐Water Contamination (7)

   ☐Other, e.g. technological emergency (8)

   (Please describe) ____

   ☐Complex event (Multiple events) (9)

   (Specify causes) ____

2.1.1 Infectious Disease Outbreak

6a-1) What infectious disease was responsible for the outbreak?
(Pre-fill if possible and verify. Circle appropriate disease.)

Anthrax
Arboviral diseases
Botulism
Brucellosis
California serogroup virus
Chancroid
Chlamydia trachomatis infections
Cholera
Coccidioidomycosis
Cryptosporidiosis
Cyclosporiasis
Diphtheria
Eastern equine encephalitis virus
Ehrlichiosis/Anaplasmosis
Giardiasis
Gonorrhea
Haemophilus influenzae, invasive disease
Hansen disease (Leprosy)
Hantavirus pulmonary syndrome
Hemolytic uremic syndrome, post-diarrheal
Hepatitis A
Hepatitis B
Hepatitis C
Human Immunodeficiency Virus (HIV) diagnosis
Influenza-associated pediatric mortality
Legionellosis
Listeriosis
Lyme disease
Malaria
Measles
Meningococcal disease
Mumps
Novel influenza A virus infections
Pertussis
Plague
Poliomyelitis, paralytic
Poliovirus infection, nonparalytic
Powassan virus
Psittacosis
Q fever
Rabies - Animal
Rabies - Human
Rocky Mountain spotted fever
Rubella
Salmonellosis
SARS and SARS Co-V
Shiga toxin-producing E. coli (STEC)
Shigellosis
Smallpox
St. Louis encephalitis virus
Streptococcal disease, invasive, Group A
Streptococcal toxic-shock syndrome
Streptococcus pneumonia
Syphilis
Tetanus
Toxic-shock syndrome (other than streptococcal)
Trichinellosis
Tuberculosis
Tularemia
Typhoid fever
Vancomycin-intermediate Staphylococcus aureus (VISA) infection
Vancomycin-resistant Staphylococcus aureus (VRSA) infection
Varicella (Chicken pox)
Vibriosis
West Nile virus
Western equine encephalitis virus
Yellow fever
Other (Write-in agent)________________________________

2.1.2 Infectious Disease Outbreak

6a-2) What was the primary mode of transmission?
(Pre-fill & verify. Check all that apply)

☐Food-borne (1)

☐Water-borne (2)

☐Vector-borne (3)

☐Airborne/Droplet (4)

☐Vertical transmission (5)

☐Human contact (direct / indirect) (6)

☐Animal contact (direct / indirect) (7)

☐Other vehicle-borne (8)

☐Unknown transmission (9)

☐Other (Please describe) (10) ________________________________

2.2.1 Severe Weather / Natural Disaster

6b-1) What type of severe weather or natural disaster was this event?
(Open-ended, potentially pre-fill & verify)

☐Flooding (1)

☐Severe winter weather (e.g., ice storm) (2)

☐Severe summer weather (3)

☐Fire (4)

☐Hurricane (5)

☐Tornado (6)

☐Tsunami (7)

☐Earthquake (8)

☐Mudslide (9)

☐Other (Please describe) (10) ________________________________

2.3.1 Chemical/Radiation/Bioterrorism/Water Contamination Event

If "Chemical, Bioterrorism, or Water Contamination Event"

6c-1) What type of [chemical(s), contamination, or bioterrorism agent] was/were involved in this event? *(Open-ended, potentially pre-fill & verify)*

____

If "Radiation Event"

6c-2) What type of radiation (or radioisotope) was involved in this event?

(Open-ended, potentially pre-fill & verify)

____

Types of radiation:

- *Nonionizing (e.g. UV radiation)*
- *Ionizing (e.g. x-rays, nuclear)*

Types of radioactive emissions:

- *Alpha particles (e.g. polonium-210, radon-222, radium-226, americium-241)*
- *Beta particles (e.g. hydrogen-3 (tritium), carbon-14, phosphorus-32, sulfur-35)*
- *X-rays*
- *Gamma rays (e.g. technetium-99m, iodine-125, iodine-131, cobalt-57, cesium-137)*

2.3.2 Chemical/Radiation/Bioterrorism Exposure/Water Contamination

6c-3) What was the cause of the [chemical, radiation, or bioterrorism event]? *(Open-ended. Check all that apply.)*

☐Industrial accident or spill (1)

☐Agricultural incident (2)

☐Household accident or spill (3)

☐Severe weather or natural disaster (4)

☐Intentional release (5)

☐Intentional or accidental misuse of prescription medications / Illegal drugs (6)

☐Other (7) ________________________________

☐Don't Know/Unable to answer (8)

If "Chemical or Bioterrorism Event or Water Contamination"

6c-4) Through which of the following routes were cases exposed, or was there potential for exposure? *(Read aloud. Check all that apply.)*

☐Inhalation (1)

☐Ingestion (2)

☐Direct contact (3)

☐Other (4) ________________________

☐Don't Know/Unable to answer (5)

If "Radiation Event"

6c-5) Through which of the following routes were people exposed, or was there potential for exposure? *(Read aloud. Check all that apply.)*

☐Inhalation (1)

☐Ingestion (2)

☐Direct contact (absorption/injection) (3)

☐External exposure (e.g. radiation source = equipment) (4)

☐Other (5) ________________________

☐Don't Know/Unable to answer (6)

2.4.1 Mass Casualty or Other Event

6d-1) What was the cause of this event?
(Please be as specific as possible, e.g. explosion, bridge collapse).

____

2.5.1 Event Size & Severity

7) ***Approximately how many individuals within your community did your health department directly contact – either to assess risk/exposure or follow-up on illness or injury?***
(If "no", enter zero; If "yes", enter # or "YES" if number unknown; If "Don't Know", write "DK")
a)____________________ b)__________ c)______________________________
\# Within Jurisdiction # Total Units (Region, State, Event)

8) ***Were any confirmed cases of illness/injury identified?***
(If "no", enter zero; If "yes", enter # or "YES" if number unknown; If "Don't Know", write "DK")
a)____________________ b)__________ c)______________________________
\# Within Jurisdiction # Total Units (Region, State, Event)

9) ***Were any severe cases (hospitalized/deaths) identified?***
(If "no", enter zero; If "yes", enter # or "YES" if number unknown; If "Don't Know", write "DK")
a)____________________ b)__________ c)______________________________
\# Within Jurisdiction # Total Units (Region, State, Event)

----

10) ***Can you think of any other indicators that might capture the severity of this*** [ ] ***event?***

☐No (0) Comments____

☐Yes (1)

10b) During the response to this event, were there any concurrent urgent events?

☐No (0)

☐Yes (1), Specify ______________________________

☐Don't know/Unable to answer (3)

11) Were any public health, environmental health, or medical services disrupted as a result of this event? *(Directly or indirectly, due to staff diversions for response efforts)*

☐No services disrupted (1)
☐Water services (2)
☐Sewage services (3)
☐Power/electricity (4)
☐Roads/transportation (5)
☐Other public health services (6), Describe ______________________________
☐ Medical services (7)
☐Other (8), Describe ______________________________
☐Don't Know/Did not ask (9)

2.6.1 Event Location

I'm going to move on to a set of questions that has to do with the location of the event and who was affected.

12) ***What types of settings were most affected during this*** [ ] ***event (e.g., skilled nursing facilities, day care centers, restaurants)?***
(Open-ended. Check all that apply.)

☐Individual/Households (1)

☐Congregate housing facilities (2)

☐Educational facilities/Day care centers (3)

☐Healthcare facilities (4)

☐Recreational facilities (5)

☐Restaurants/Grocery stores (6)

☐No specific settings (7)

☐Other (8)

☐Don't Know/Unable to answer (9)

13) ***How widespread was this*** [ ] ***event in terms of geography?***
(Potentially pre-fill. Open-ended. Choose one response.)

☐Very localized (New definition: Illness or exposure in one defined setting) (1)

☐Very localized, but with wider geographic scope (New definition: Geographically dispersed illness or exposure related to a specific behavior, product, or setting) (2)

☐Local (New definition: General population potentially exposed or affected) (3)

☐Regional (No longer valid response) (4)

☐Widespread (No longer valid response) (5)

☐Unknown (6)

☐Don't Know/Unable to answer (7)

13b) Exposed persons were residents of:

( ) Only 1 LHD jurisdiction (0)
( ) Multiple LHD jurisdictions, one state (1)
( ) Multiple LHD jurisdictions multiple states (2)
( ) Multiple countries, single US State (3)
( ) Multiple countries, multiple US states (4)

( ) DK (5)

2.7.1 Populations Affected

14) Were any specific population(s) within those settings disproportionately affected by this [ ] ***event, or was it just the general population?***
(Open-ended. Check <u>all that apply</u>.)

❑Occupational populations (e.g., health care workers, those who work outdoors)(1)

❑Pregnant women (2)

❑Infants (0-3 years) (3)

❑Children/Adolescents (3-18 years) (4)

❑Senior citizens (5)

❑Low income individuals (6)

❑Persons with chronic medical conditions (7)

❑Rural or geographically isolated individuals (8)

❑Transient populations (e.g. homeless, migrant workers, tourists) (9)

❑Persons functionally at-risk (communication, transportation, medical care, supervision) (10)

❑Persons living in congregate housing situations (e.g. dormitories) (11)

❑General population was equally affected (personal characteristics not related to susceptibility) (12)

❑Other (Please describe) (13) ______________________________

❑Don't Know/Unable to answer (14)

Block 3: Response Characteristics

3.1.1 LHD Notification

If Severe Weather Event (or possible to have advance warning of event)

15) Did your health department have any advance warning before the [ ] event began?

☐ No (0)

☐ Yes (1) → Skip Q16

☐Don't Know/Unable to answer (2)

Ask if "No" advance warning before event:

16) Think back to when your health department was first notified about the event. If you were to rate the time of notification on a scale from 1-5 (with 1 being at the very beginning of the event, and 5 being at the very end), how would you rate the time of your notification?

At the very beginning (1)	2	3	4	At the very end (5)	Don't know (6)	N/A; Difficult to Define (7)
☐	☐	☐	☐	☐	☐	☐

Comments:

17) How did you <u>first</u> learn about this [   ] ***event?***
(Open-ended. Choose <u>one</u> response.)

☐Notification by hospital or healthcare system (1)

☐Notification by clinician (2)

☐Notification by other health department (3)

☐Notification by state health department or CDC (4)

☐Notification by individual in the community (i.e. concerned citizen) (5)

☐Notification by school or university (6)

☐Notification by media (7)

☐Other (Please describe) (8) ___________________

☐Don't Know/Unable to answer (9)

18) Is the notification by [entity that notified health department] part of a routine system for notifying you when something like this occurs (e.g. routine lab reporting as part of National Notifiable Disease reporting)?
(Open-ended)

☐No (0)

☐Yes (1)

☐Don't Know/Unable to answer (2)

3.2.1 Circumstances of LHD Involvement

19) the point when your health department became involved, had ________________ been identified as the [specific health hazard/etiologic agent]*? (Pre-fill or auto-fill based on earlier response)*

☐No (0)
☐Yes (1) → Specific health hazard? ________________________
☐Somewhat (e.g. etiologic agent highly suspected, but not yet confirmed) (2)
☐Not Applicable (3) __________________
☐Don't Know/Unable to answer (4)

20) At the point when your health department became involved, was the source of ______________________ the [specific health hazard/etiologic agent] known? *(Pre-fill or auto-fill based on earlier response)*

☐No (0)
☐Yes (1)
☐Somewhat (2)
☐Not applicable (3) __________________
☐Don't Know/Unable to answer (4)

21) Was the source of ______________________ the [specific health hazard/etiologic agent] determined at any point?

☐No (0)
☐Yes(1) → If "Yes", write in: ____
☐Don't Know/Unable to answer (2)

22) At the point when your health department became involved, was the exposure to ___________________________ the [specific health hazard/etiologic agent] ongoing? *(Open-ended)*

☐No (0)
☐Yes (1)
☐Not applicable (2) __________________
☐Don't Know/Unable to answer (3)

3.3.1 PHEP Activities

23) The next set of questions I'll ask have to do with the types of public health activities carried out in the response to this* [ ] *event. I'm going to read a list of activities and ask whether or not each activity was carried out in the response. If it was initiated, let me know which organizations/agencies contributed. I should note that some of these activities may not be relevant to your event.

A) During the response, was/were any [activity name] initiated?
B) If so, which organizations or agencies contributed to these activities?

☐ **(SEI)** ***Surveillance and/or epidemiologic activities?***

☐ **(CHA)** ***Assessment of community health or needs?***

☐ **(RCA)** ***Assessment of the public health or medical response capacity?***

☐ **(ENV)** ***Environmental investigation and/or product sampling?***

☐ **(LAB)** ***Public health laboratory testing?***

☐ **(SME)** ***Consulting subject matter experts to assess the threat and/or determine public health response activities?***

☐ **(INFO)** ***Health information exchange with other responding agencies – such as data or other situational***

☐ **(PIG)** ***Issue public health alerts or guidance to members of the public, clinical communities or other involved organizations?***

☐ **(MED)** ***Disease prevention or control measures involving medications or vaccines?***

☐ **(MMM)** ***Management of medical supplies?***

☐ **(NPI)** ***Other disease control measures? (e.g. social distancing, environmental controls)?***

☐ **(MCS)** ***Mass care or sheltering?***

☐ **(RSH)** ***Health and safety protection for incident responders?***

☐ **(SURGE)** ***Medical surge, such as use of alternate care facilities?***

☐ **(FAM)** ***Fatality management?***

☐ **(VOM)** ***Volunteer management?***

☐ **(COR)** ***Community recovery - to rebuild public health, medical, and/or mental/behavioral health systems after the event?***

☐ **(OTR)** ***Did your health department perform any additional public health activities other than those just listed?***
Describe additional PH activities in Q26, below

24) Please briefly describe those additional public health activities.

____

____

(ASK ONLY if Evacuation was mentioned as a response activity)

☐ **(EVAC)** ***Evacuation?***

Just so you're aware, you are more than half way through the survey.

24b) (CODE BASED ON PREVIOUS RESPONSES, DON'T ASK) Did the health department rely on the potential cases or family members for information regarding exposure or illness?

☐ No (0)
☐ Yes (1)
☐ Don't Know/Unable to Answer (3)

25) (CODE BASED ON PREVIOUS RESPONSES, DON'T ASK) What levels of government outside of public health were involved in the response?

☐ Local	☐ Federal
☐ State	☐ None
☐ Don't Know/Unable to answer	

26) (IF POSSIBLE, CODE BASED ON PREVIOUS RESPONSES, DON'T ASK) What level or assistance was required for this event? *(Choose only one, highest level of assistance)*

☐Did not require assistance outside of local resources (0)
☐Required assistance from within local jurisdiction (1)
☐Required assistance from outside local jurisdiction (2)
☐Don't Know (3)

3.3.2 Essential PHEP Activities

27) From your perspective, which public health response activities were most essential (i.e., were absolutely necessary to the overall response)? *(Allow for long pause after they list activities)*

☐ **(SEI)** Surveillance and/or epidemiologic activities (1)
☐ **(CHA)** Assessment of community health or needs (2)
☐ **(RCA)** Assessment of the public health or medical response capacity (3)
☐ **(ENV)** Environmental investigation and/or product sampling (4)
☐ **(LAB)** Public health laboratory testing (5)
☐ **(SME)** Consulting subject matter experts to assess threat and/or determine response activities (6)
☐ **(INFO)** Health information exchange with other responding agencies (7)
☐ **(PIG)** Issue public health alerts or guidance to members of the public, clinical communities or other involved organizations (8)
☐ **(MED)** Disease prevention or control measures involving medications or vaccines (9)
☐ **(MMM)** Management of medical supplies (10)
☐ **(NPI)** Other disease control measures (e.g. social distancing) (11)
☐ **(MCS)** Mass care or sheltering (12)
☐ **(RSH)** Health and safety protection for incident responders (13)
☐ **(SURGE)** Medical surge, such as use of alternate care facilities (14)
☐ **(FAM)** Fatality management (15)
☐ **(VOM)** Volunteer management (16)
☐ **(COR)** Community recovery–rebuilding public health, medical and/or mental/behavioral health systems (17)
☐ **(OTR)** Other (18) ______________________
☐ **(EOM)** Emergency Operations Management (19)
☐ **(PREP)** Community Preparedness (20)

28) Which sections of the health department were involved in the response?

☐ Communicable disease (1)
☐ Public health preparedness and response (2)
☐ Laboratory (3)
☐ Environmental health (4)
☐ Disease-specific branch (Circle: HIV/AIDS, TB, STD) (5)
☐ Administration (e.g. Director, health officer, commissioner) (6)
☐ Epidemiology section (7)
☐ Other (8) ____________________________________
☐ All sections (9)
☐Don't Know/Unable to answer (10)

3.4.1 Issue public health alerts or guidance to members of the public…

29) ***You mentioned that public health alerts/guidance were issued to members of the public, clinical communities or other involved organizations. Can you tell me who were the intended recipients of those communications?*** *(Open-ended. Check all that apply.)*

☐ LHD (self)
☐ LHD (other)
☐ Community members (general public)
☐ Affected community members (e.g. attendees of affected wedding)
☐ Hospital/Healthcare
☐ Other(s) ____
____
____

☐ Don't Know/Unable to answer

3.4.2 Medical Countermeasure Dispensing

30) ***You mentioned medical countermeasures such as vaccines and antivirals were dispensed. What type of medical countermeasures were used as part of the public health response (i.e., not as a part of standard clinical care)?*** *(Open-ended. Check all that apply.)*

☐Post-exposure Prophylaxis (PEP) (1)
☐Pre-exposure Prophylaxis (PrEP) (2)
☐Treatment (3)
☐Other (4) ____________
☐Don't Know/Unable to answer (5)

If PEP, PrEP or Treatment are selected, ask for # of individuals, below:

31) ***Altogether, approximately how many individuals received (post-exposure prophylaxis, pre-exposure prophylaxis or treatment) during this response?***

PEP / PrEP / Treatment: ____________________

☐ Don't Know/Unable to answer

3.4.3 Non-Pharmaceutical Interventions

32) ***Following up on [other] disease control or prevention activities, what types of interventions were implemented or recommended?*** *(Open-ended, check all that apply).*

☐**(ISO)** Isolation of cases (1)
☐**(QAR)** Quarantine of contacts (2)
☐**(EXCL)** Exclude persons from activities (e.g. food handlers from work) (3)
☐**(SHLTR)** Sheltering of unexposed (4)
☐**(CLOSE)** Establishment closure (e.g. school, venues for mass gatherings)
☐**(TRVL)** Restrictions on movement/travel (6)
☐**(RECS)** Recommendations for social interventions to reduce contact rate (e.g. social distancing)(7)

☐**(DECON)** Environmental or product decontamination (8)
☐**(ECO)** Environmental or ecological interventions (e.g. insecticide spraying) (9)
☐**(ENGIN)** Engineering controls (e.g. installation of water or air filtration)
☐**(RECALL)** Product advisory or recall/Disposal order (11)
☐**(BOIL)** Boil water order (12)
☐**(RECE)** Recommendations for physical or environmental interventions (e.g. use of PPE) (13)

☐**(ANISO)** Isolation/Quarantine (14)
☐**(EUTH)** Euthanize/culling animals (15)

☐**(OTHR)** Other (16) ____________________
☐Don't Know/Unable to answer (17)

3.4.4 Surveillance & Epidemiologic Investigations

33) You mentioned that surveillance/epidemiologic investigations were carried out. What types of activities were conducted in this area?
(Open-ended. Check all that apply.)

☐Case finding (1)

☐Descriptive Epi (line list, epi curve, descriptive analysis) (10)

☐Screening (2)

☐Contact tracing/Household contact tracing (3)

☐Root Cause Analysis (interpret results of epi, lab, clinical, environmental, etc.) (4)

☐Use epi/surveillance data to recommend control measures (5)

☐Use epi/surveillance data to identify individuals/populations at-risk (6)

☐Conduct analytic study (case/control or cohort study) (7)

☐Other (8) ____________________

☐Don't Know/Unable to answer (9)

3.4.5 Emergency operations management

34) Were any emergency operations management centers activated to support the local public health response? *(Open-ended. Choose one response.)*

☐No (0)
☐Yes (1) → If selected, ask what type and which key organizations/agencies participated
☐Don't Know/Unable to answer (2)

35) What types of emergency operations management centers were activated?
(Open-ended. Check all that apply.)

☐City/county Emergency Operations Center (1)
☐Public Health Departmental Operations Center (2)
☐Regional or State Public Health Emergency Operations Center (3)
☐Other (4) ____________________
☐Don't Know/Unable to answer (5)

36) Which were the key organizations/agencies that participated in the emergency operations management? *(Open-ended. Check all that apply.)*

3.5 Other

37) As a mechanism to enforce disease control and prevention measures, did you implement any of the following? *(Read aloud. Check <u>all that apply</u>)*

☐Regulatory or law enforcement action (1)

☐Change in policy (2)

☐None of the above (3)

☐Don't Know/Unable to answer (4)

38) What was the approximate duration of your health department's involvement in the response to this event? (in days, weeks, or months).

Length of time ________________________

☐ Days Comments:

☐ Weeks

☐ Months

☐ Years

38b) Was there any internal or extra-organizational debate about the severity of the event or scope of the response?

☐No (0)

☐Yes (1), Specify ____________________________

☐Don't know/Unable to answer (3)

3.5.1 Role of Public Health in Overall Response

39) Now, thinking about the role of public health in the overall response to the event, would you say that public health played a lead role, a supporting role, or that it was a joint effort between public health and other responding agencies?

❑Supporting role (1)

❑Joint-effort (2)

❑Leading role (3)

❑Don't Know/Unable to answer (4)

Take notes on additional comments on public health's role in overall response.

____
____
____
____

40) How often does your health department respond to a similar event on this scale? *(Open-ended)*

❑Very infrequently (this is the only event of its kind in recent history) (0)
❑Infrequently (less than once every few years) (1)
❑Sometimes (1-2 times per year) (2)
❑Frequently (3-5 times per year) (3)
❑Very Frequently (more than 5 times per year) (4)
❑Don't Know/Unable to answer (5)

41) Has your health department published a report about your response, either in the peer-reviewed literature, on an informal sharing site, or as an After-Action Report?

☐No (0)
☐Yes (1) → If selected, ask if health dept published or shared; see below
☐Don't Know/Unable to answer (2)

42) Where did your health department publish or share about the event response? *(Read aloud. Check all that apply.)*

☐Peer-reviewed journal (1)

☐MMWR (2)

☐Information-sharing database (3)

☐After Action Report (4) → If selected, ask where AAR was distributed; see below

☐Other (Please specify) (5) ____________________

☐Don't Know/Unable to answer (6)

43) Where was the AAR distributed?

☐Internally (1)
☐Contributing agencies (2)
☐State health department (3)
☐Other (4) (Please specify) ____________________
☐Don't Know/Unable to answer (5)

44) On a scale from 1-5, how would you rate the effectiveness of the overall response (with 1 being it met no needs to 5 being it fully met needs)? *(Open-ended)*

Comments:

____
____
____

45) ***Why did you choose this specific event as the focus of the interview?***

____
____
____
____

46) ***That concludes my questions. At this point, do you feel that there are important aspects of the event that we haven't touched upon?***

____
____
____
____

END OF SURVEY

Thank you very much for your time and participation! If we have brief clarifying questions, is it ok to contact you?

Thank you again! If you have any questions or comments you can reach us at smallhazards@berkeley.edu.

Complete interview? ☐ No ☐ Yes *If "No", reason: ______________________________
Length of interview: __________

FOR INTERVEWER:

48) What do you think were the health department's primary concerns during this event?

____
____
____

49) Any final reflections or notes?

____
____
____

Admin Team use only: Date __________ Time __________ submitted to Qualtrics