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Methodological considerations in pre- and post-emergency network identification and data collection for disaster risk reduction: Lessons from wildfire response networks in the American Northwest

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ABSTRACT

While social network analysis continues to enjoy considerable attention, literature on social network data collection often lacks explicit attention to methods. This presents special challenges to approaching the problems of undertaking social network analysis and of studying disaster preparedness, planning, and, ultimately, risk reduction. In this paper, we address this issue by presenting our synthesis of several strategies for network analyses from our processes for network identification and data collection in a longitudinal study of multi-jurisdictional, inter-agency wildfire response networks in the American Northwest. In the course of this ongoing project, the process of detecting and collecting data on pre-existing and emergent networks in the real world was not a matter of one theoretical or empirical judgement, but rather several. We alternated between: (1) spatio-ecological detection of jurisdictions adjacent to areas at-risk for large wildfires; (2) a hybrid approach to selecting actors and agencies identified as common participants in wildfire response networks; and (3) event-based detections of parties to specific wildfire response networks. We conclude with steps for thinking through network identification and bounding, integrating networks, conceptualizing rosters and ties in initial and events-based phases, and how to manage longitudinal network data collection.

1. Introduction

> "I have a ton of books/papers on SNA, but it's just a bit unclear to me which methodology would be most appropriate given the research questions I'm interested in and given the specifics of the sites."
> *Anonymous Social Scientist*

There is broad agreement in the literature that complex disasters are beyond the scope of any single organization or agency to address [1,2]. Consequently, the field of disaster studies has committed significant effort to understanding network forms of governance before, during, and following significant disasters [3–6]. Increasingly, evidence points to the need to assess relationships between responders as a central variable in preparedness [7], taking into account communication and coordination between sectors and between agencies [8,9]. While hierarchical network studies—where lead and subordinate actors and their affiliations to higher order units are clearly established—are effective for hazard and physical resource mapping [10], disaster risk reduction and preparedness efforts need to consider the nonhierarchical, complex relational dynamics and emergent aspects of network formation in emergency response (e.g., Refs. [11,12,45]).

Response preparedness is an important element of disaster risk reduction, so there is a need to develop new methodologies to understand parameters that are often difficult to conceptualize before disasters come to pass [2]. Researchers often find themselves studying disaster response *retrospectively*, collecting information after a disaster to understand what capabilities and limitations existed beforehand that set the stage for response capacity. This is an inherent challenge in the field, as we rarely know where disasters will occur until after the fact. Determining when and where to collect pre-incident network data requires some combination of establishing a large sample frame (and subsequently mass data collection) and the formidable task of anticipating future emergencies. Our interest lies in the longitudinal relationship of pre-event networks to event-based networks and because we aimed to collect pre-existing relational ties prior to the incidents, our challenge was how to determine pre-incident network relationships to future incidents.

One major obstacle to developing a complex social networks research agenda for disaster risk reduction is the fact that the methodology is largely understood only by those who already work in the field, with many barriers to entry, even for seasoned researchers and methodologists. The epigraph comes from an email from a colleague to the lead author. Its message illuminated an important gap in the

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literature situated between the well-known texts on social network analysis methods and techniques (e.g. Refs. [13,14]), and the wealth of readings dedicated to applied fieldwork (e.g., Ref. [15]). This gap concerns the techniques and considerations for conceptualizing and operationalizing network data collection in messy real-world settings. There are countless books and articles on social network research methodology, often focused on conceptual features (e.g., whole or personal networks), analytical procedures (e.g., comparing measures of centrality), and an array of software packages to structure and compute relational data. However, collecting original relational data—whether relations between actors are self-determined or researcher-imposed—presents daunting challenges that are seldom discussed in detail in the research literature [16]. Authors assess and debate the relative merits of *elicitation* strategies (e.g., name generators vs. position generators, respondent burden, recall, bias) and diverse network measures, but scant attention is paid to actual processes of *collecting* network data. Once a researcher has identified the network phenomenon they aim to study, how do they actually go about obtaining data in real world settings?

There are several theoretical and data-driven decisions a researcher must make over the course of identifying a network and determining its boundaries [16]. This is rendered more complex when operationalizing inter-organizational networks and deciding how to determine relational ties among them. In this article, we present our synthesis of several strategies for network identification and data collection from our experience in a longitudinal study of wildfire response networks in the American Northwest. In Part I, we present the first phase of our recursive, longitudinal design for pre-fire network boundary and roster identification. In Part II, we detail our event-based network boundary and roster identification and address how these approaches align with existing ideas about network analysis, while challenging some notions about network data collection. We chose to write this article in the first person to share a realistic narrative of the strategic decisions, problems, and corrections made based on dynamic processes unfolding in the real world. It is our objective to reduce barriers to entry to social network research for disaster risk reduction.

2. Part I: pre-wildfire response networks

2.1. Whole network boundaries: conceptual and methodological challenges

Network analyses are generally either ego-centric, meaning they focus on relationships between a given actor (ego) and others (alters); or whole (or socio-centric) networks, which refers to total patterns of relations between a defined set of actors. Determining whole-network boundaries can be straightforward, as when dealing with a bounded organization (e.g., a school) or unit (e.g., a classroom), but it becomes more challenging when there are no recognized criteria of boundedness ([17]:69), such as determining who is or is not a part of a given process.

The four primary approaches to determining network boundaries include what we describe as spatio-ecological, and others defined as relational, positional (or attribute based), and event-based [16–18]. Our spatio-ecological approach considers networks within certain geospatial and jurisdictional parameters. Relational approaches can be *nominal*, based on researchers' theories regarding relations between a given set of actors, or *realist*, based on boundaries set by respondent nominations of alters. *Positional* approaches identify people sharing common attributes or positions (e.g., occupation), often associated with an organization [19]. Still, inclusion and exclusion of particular attributes must be conceptually justified. The relational approach can be based on *a priori* knowledge about relations between a given set of actors (nominal) or respondent nominations of alters for inclusion (realist), such as snowball sampling or free-listing.

To identify pre-incident networks, we used two network-bounding approaches, which included: (1) spatio-ecological detection of jurisdictions adjacent to areas at-risk for large wildfires; and (2) a hybrid of nominal and positional selections of actors and agencies identified as common participants in wildfire response networks. These principal approaches served as guiding frameworks for our study, which we complemented by triangulating jurisdictional adjacencies and network membership with participants (themselves members of our theoretically bounded network) at each stage. This could not, *sensu stricto*, be considered a realist approach where network members themselves define membership. Still, we asked informants to tell us about people who met specific criteria *as defined by our research team*.

2.2. Inter-organizational and social network analyses: first steps toward a synthesis

There is currently limited integration between research in the areas of social network analysis and inter-organizational networks [20,21]. Some of this is due to real distinctions in organizational and individual levels of analysis, but Carsten Bergenholtz and Christian Waldstrøm [20] make clear that, while inter-organizational networks can be conceived of as metaphors for multi-agency interdependencies, it is feasible to analyze the social structure between organizations. Branda Nowell and Toddi Steelman [22] contributed to a synthesis of the two approaches by highlighting the role of organizational leaders in facilitating inter-organizational communication and coordination in disaster response.

Network metrics are sociological constructs subject to the same validity challenges faced in measuring any social phenomenon. Considering this, the researcher is left with no other choice but to bound the network to maximize the theoretical comparability of network ties across organizations—that is, to collect the same information about ties from different organizations. This generally requires selecting role-equivalent representatives in each organization. What is important in these design choices is generally not that every possible network connection between two organizations be captured, but rather that a theoretically definable, meaningful, and methodologically comparable network—where organizations are identified and represented equivalently—is captured. The researcher must then make a compelling argument for why the chosen sampling/boundary conditions that define the network are the most theoretically meaningful, given the phenomenon under investigation [16]. We revisit this argument in Part II, below.

2.3. Rosters and ties: collecting whole network data

Two common approaches to whole network data collection are to work from archival ([17]:74) or log ([23]:50) data. Artifacts such as memoranda of understanding and disaster response plans can illuminate some of the institutional structure for response in place before a disaster; however, research has suggested these documents can be problematic indicators of actual network formation (e.g., Ref. [24]). Several recent studies have considered complex network formation in response to disasters and catastrophic events using similar sources. Alireza Abbasi and Naim Kapucu [3] studied evolving networks in response to four hurricanes in Florida by conducting content analysis on situation reports issued by the Florida State Emergency Response Team (SERT) prior to, during, and following the hurricanes. Kapucu and colleagues [25] studied inter-organizational response to the 2005 US Gulf Coast Hurricanes Katrina and Rita by conducting content analysis on news reports, FEMA situation reports, and several subsequent state and federal government reports. Louise Comfort and Naim Kapucu's [26] study of inter-organizational coordination in response to the September 11, 2001 terrorist attacks in New York City employed content analysis of FEMA situation reports and press accounts, in which they identified a response network comprised of 456 organizations. They complemented this with interviews with operations personnel from FEMA and other federal agencies, though they do not report how interviews informed network construction, boundary definition, or performance.

While the above studies and methodological approaches have identified important network dynamics in emergencies, the efficacy of the methods employed is largely restricted to post-hoc analysis. One exception is Xuesong Guo and Naim Kapucu's [27] study of planned networks, actual networks, and influence structures in response to the 2008 Wenchuan earthquake in China. Their methods entailed identifying participating organizations in a report issued by the Shaanxi Emergency Management Office, determining boundaries based on "experts' suggestions", and surveying executive directors or managers about their organizational participation and influence in the network ([27]; 207). One avenue available to us would have been to study extant memoranda of understanding (MOUs) and mutual aid agreements between jurisdictions in order to map pre-existing networks between certain limited actors. However, they tend to highlight connections between limited types of actors in the response network, such as fire operations, over local government actors and utilities that have multiple functions beyond immediate response. Moreover, as we discuss below, we did utilize wildfire situation reports as a key source of data on incident selection and early network activation. Importantly, we were also concerned to build our networks out of interview data because of evidence suggesting that network formation is based on *socially* embedded relationships, not solely *institutionally* embedded relationships [22].

Örjan Bodin and Daniel Nohrstedt's [4] study of the formation of collaborative disaster management networks in response to a wildfire in Sweden comes closest to our approach. They conducted in-depth interviews with 16 individuals engaged in the "acute phase" of the wildfire response to develop a survey administered to 129 individuals in four of the most affected municipalities and in the operational headquarters. This enabled them to identify what they call "the bulk of the crisis response organization … during the acute phase of the fire" ([4]; 187). However, they acknowledge that they intentionally excluded fire fighters and others working directly in fire suppression. They also excluded a short list of actors whom interviewees identified as working closely with others already in the network roster. Here again, this study was restricted to post-hoc analysis of network performance, rather than considering pre-disaster networks and their influence on the emergence and formation of response networks. Our objectives were to understand the relationship between pre-existing networks and actual emergency response networks.

Disaster response dynamics are in many ways unique to the specific contexts in which they emerge, which creates a challenge in the field as we seek to identify global lessons that transcend context. That said, there are many common processes and challenges to studying networks in complex environments. Wildfire is an emergency context that is well suited for study due to its relative regularity in defined geographic spaces compared to other types of disasters such as tsunamis and earthquakes. Wildfire in the wildland-urban interface also shares many characteristics with other disasters in having an active emergency response phase involving common processes such as evacuation, road closures, utility restoration, evacuee mass care, and re-housing. However, the study of wildfires necessitates consideration of several key attributes distinct from some other disaster contexts. They are somewhat unique in that incident response includes fire suppression and emergency management components. Agencies and professionals do not attempt to change the biophysical environment to "herd" tornados, tsunamis, or hurricanes away from communities. They mitigate as best they can but once the incident occurs, major operations are in the domain of evacuation and emergency response. Wildfire suppression efforts, however, do attempt to alter the biophysical environment to protect values at risk while the fire is active. This makes for operationally dynamic emergency response and suppression operations involving coordinated response to changing conditions on the ground. Appreciation of both operational domains and their relationship to each other during a fire is critical to understanding response networks during wildfires [16].

We address the gaps we have identified in methodological details regarding whole network data collection for pre-disaster and emergent disaster network formation. Our approach, though designed for wildfire preparedness and response, addresses many issues that are present in other disaster and non-disaster network contexts including policy networks, environmental impact assessments, and other events that are emergent or involve complex problem domains. This approach comprised two primary phases—pre-fire and incident-based network identification—both of which entailed multiple complementary methods and strategies for triangulation.

2.4. Adjacency matrices: how did we identify pre-fire network boundaries and rosters?

Collecting longitudinal data on networks before and during emergencies creates numerous design challenges stemming from the largely reactive nature of incident response networks. This is particularly hard if data are non-retrospective—collected prior to an emergency. But this is not unique to researchers, as emergency managers and other officials and practitioners tasked with preparedness activities face similar challenges in building capacity within latent networks of responders who may need to coordinate efforts in the event of an emergency. We therefore followed the lead of these professionals and set out to identify 'likely' networks. We conceptualized these networks based on geographic adjacencies and probabilities, including the likelihood of a disaster in a given area.

Pre-fire network boundary identification entailed selecting areas and jurisdictions at risk for wildfire at the wildland-urban interface, building a matrix of these spatial and jurisdictional adjacencies, and confirming our adjacency matrices with key informants (see Table 1). Network roster development at this stage involved identifying organizations and organizational personnel in each matrix of adjacent jurisdictions and confirming rosters with key informants. In this initial stage, we were concerned with two spatio-ecological questions: what jurisdictions are adjacent to areas at risk for wildfire? And which of these jurisdictions are adjacent to one another, such that they would be likely to mobilize in response to the same incidents? Following this, we were concerned with nominal-positional questions of first determining the organizations (or organizational units) most likely to participate in wildfire response and then identifying leaders within each organization (or unit). We elected to focus specifically on leaders because the Incident Command System that governs disaster response coordination in this context relies heavily on formal roles and authority. Because our interest was in communication and coordination among agencies and organizations, we deemed understanding relational ties between those actors formally responsible for coordinating their agency's operations with the rest of the network the most information rich. However, this strategy carried with it the risk that we missed some aspects of informal coordination that occurred outside of the chain of command, so we focused on risk of wildfire from USFS lands in order to create networks that are more comparable across the study.

2.4.1. Human-environment relations: place selection and establishing administrative boundaries

To identify pre-fire season networks, we had to determine appropriate geographic boundaries. First, we chose to focus on the four states of Idaho, Montana, Oregon, and Washington, due to the higher projected risk (over other regions in the continental United States) of long-term wildfire threat shown in climate change models [28,29]. Second, we located key administrative boundaries within which to begin mapping our networks. We identified National Forest ranger districts in areas with populations potentially at risk for wildfires and subsequently identified 137 wildfire-prone districts on 33 National Forests and entered them into ArcMap 10 [30] to create a geographic information system (GIS). To map jurisdictions, we began identifying administrative

Table 1
Stages of pre-fire network bounding & detection.

Network Bounding Approach	Method of Detection	Data	Triangulation
Spatio-ecological	Mapping jurisdictions adjacent to areas at-risk for large wildfires	Step 1 - Selecting states meeting study criteria (large national forests, past wildfires, and projected increased wildfire in climate models) Step 2 - Mapped adjacent administrative boundaries (within historical range of past fires) Step 3 - Eliminate adjacencies with geological features (river valley, canyon) that impede wildfire spread	Interview local expert key informants to confirm administrative boundaries and rosters
Hybrid nominal and positional selections of actors and agencies	Actors and agencies identified as common participants in incident (wildfire response networks)	*Municipal & County Agencies & Personnel* Step 1 - Compile agency rosters for each county and municipality using public lists and web searches Step 2 - Contact county registrar for agencies and agency contacts *USFS Districts & Personnel* US Forest Service employee directory for personnel information	Step 1 - Direct contact with each identified individual in each agency to confirm position and contact information Step 2 - Interview key informants in each jurisdiction to correct and confirm rosters Step 1 - Contact each headquarters and district and confirmed or obtained names of personnel Step 2 - Cross-reference employee directory to confirm and correct Step 3 - Pilot network survey with local expert key informants

boundaries in the wildland-urban interface (WUI), where forest and significant human settlements overlap. Using our GIS and data from the Geographic Names Information System (GNIS) database, we examined county and municipal boundaries in relation to National Forest boundaries. We then selected those areas with population centers (municipalities and Census Designated Places) within twelve miles[1] of a National Forest boundary, signifying risk for a wildfire within the wildland-urban interface. We could then identify counties and population centers potentially at risk in a wildfire, and specifically identify those that were adjacent to particular National Forest districts and therefore likely members of shared wildfire preparedness and response networks. This process of linking districts to counties with at-risk population centers produced an initial list of 137 counties.

While GNIS data provided consistency across our sample area, the theoretical sample of interest was areas facing the threat of a WUI fire. Community proximity to a National Forest boundary provided an initial indicator of risk, but topographic features (e.g., valley, canyon, river) could mitigate such a risk. Not all county and population center-related details necessary for choosing our sample frame were available, and we therefore had to make revisions using other sources of data. Specifically, we employed a key informant interview strategy—-common in the social sciences—to confirm our network boundaries and rosters by asking USFS Fire Management Officers (FMOs; n = 134) to validate our lists of counties and districts. In phone interviews, we asked FMOs whether jurisdictions adjacent to their districts (ranging from one to eight counties per district) had populations at risk for a wildfire burning off their districts. We asked this in three different ways to confirm our findings:

- Does this county have a significant population center within twelve miles of your district that would be at risk for a WUI fire?
- How at risk is [*county name*] for a wildfire that was ignited in your district and could result in the loss or damage of homes, critical infrastructure and businesses?
- For each county identified as no or low risk: our records indicated that these [*community names*] communities are within twelve miles of the Forest Service border. Are these communities at risk for a WUI fire?

We used information from these interviews to audit counties in our master list. If respondents reported communities were not at risk, we relied on a follow-up question asking interviewees if they could explain why not. We used these notes to determine whether the county was at no risk or low risk. We consulted USFS maps available online to evaluate discrepancies in respondent and researcher risk assessments. In eight cases, interview data and maps either provided insufficient information and/or key informants had only been in their positions for a few months and were unsure of population center proximity or fire risk for a certain county. We therefore retained those counties in our sample frame. After our audit of counties at risk in our sample, we pared our initial list of 137 counties down to 109. We assigned each county, state, forest, and district a unique identification number and created an adjacency matrix—a spreadsheet listing each district-to-county adjacency in the sample. We later used this matrix to develop our master networks in pre-fire and incident-based network surveys.

2.4.2. Building the network roster: local and federal agencies and personnel

Once we identified the counties and districts of interest, we moved on to identify responder networks for each county in our sample for our pre-fire responder survey. A responder network is defined as "the collection of individuals, organizations, and agencies that have sustained involvement during the event who aim to serve the community in minimizing and coping with damages brought on by the disaster" ([31]; 235). This is similar to Bodin and Nohrstedt's [4] operationalization of response networks; however, while they bracketed out fire service, we included fire service personnel because our own prior research[2] identified them as active participants in network formation beyond fire suppression. We then moved to identify specific organizational leaders (i.e., positions) within this otherwise nominal framework who would serve as the population for our pre-fire survey. Based on past fieldwork on wildfires in the American West, we developed an initial list of probable local[3] and federal[4] responding organization leadership roles

[1] This procedure was not to identify WUI areas. Rather, our examination of 2011 ICS-209 reports that revealed twelve miles as the approximate maximum distance from US Forest Service boundaries for populated areas requiring evacuation in WUI fires.

[2] Wildfire incidents: Bull (CA, 2010), Fourmile Canyon (CO, 2010), Schultz (AZ, 2010), Tecolote (NM, 2010), Hat Creek (CA, 2009), GAP (CA, 2008), Cascade (MT, 2008), Gunbarrel (WY, 2008).

[3] County emergency managers (OEM), sheriffs, fire departments, administrators, and commissioners, as well as mayor's offices, municipal administrators, animal rescue, and the American Red Cross.

[4] Forest Supervisors, Fire Staff Officers, Public Affairs Officers (PAO), Safety Officers, Resource Advisors (environmental and cultural), Tribal Liaisons, and Finance Officers (dealing with cost share) at the Forest level, and Fire Management Officers (FMO), District Rangers, Law Enforcement Officers (LEO), and PAOs at the district level.

by type[5] [32]. We then found specific contacts for this using professional directories, Internet searches, and calling county and USFS representatives to identify individuals in applicable positions.

Since networks and organizational staffing change, we revised our network rosters at several stages during our initial network identification and subsequent survey implementation. Revisions were prompted by attrition (retirement, turnover, etc.), administrative mergers (forest and county fire districts), or the discovery of simple errors. To ensure network accuracy, we updated them weekly throughout our key informant interview and survey implementation processes (between November 2012 and April 2013).

2.4.3. Building municipal and county network rosters

To identify individuals positioned in our theoretical responder network, we used an iterative strategy, relying heavily on triangulation at each stage to confirm information from multiple sources and correcting previous findings when necessary. Ideally, we would obtain directories and then call to confirm and complete information (e.g., best email address) with each informant. But directories were often unavailable, and we had to rely on Internet searches. Failing that, we turned to key local informants for local agency information—among them, county clerks proved especially helpful. Each approach had its limitations, which differed across jurisdictions. In all instances, we called roster targets to confirm names and contact information. Though time consuming, this final direct confirmation strategy proved critical, as directories (and occasionally, contacts from key informants) were sometimes outdated or participants requested contact via alternate phones and emails. In all, we identified 1781 individuals in 1432 municipal, county, and state organizations across our sample area. Rosters ranged in size from 12 to 72 alters, depending on the number of adjacent jurisdictions.

2.4.4. Building United States Forest Service rosters

Federal agencies pose unique challenges to network boundary decisions regarding conceptually equivalent actors within networks, particularly when examining interaction with local responders in an emergency. For instance, while a rural county sheriff generally has a relatively limited geographic focus, a singular mission, and one or two agency representatives on an incident, a National Forest is a large bureaucracy with numerous individuals representing different units associated with various functional areas and across several separately governed districts. Consequently, to form the USFS portion of our pre-fire season response networks, we needed to identify the core units within the agency with formal roles and responsibilities during wildfires, and then identify who represented the agency to the rest of the network in relation to that specific unit/function. In the resulting sample, each member of the network represented a different unit or functional specialization expected to have an externally facing coordination role with the rest of the network. Building USFS rosters, which ranged in size from 23 to 133, was relatively straightforward compared to county networks because Forests use equivalent positions and there was less need to evaluate whether to include certain positions.

To collect contacts for positions of interest, we consulted USFS employee lists for personnel information. After filling in as many positions in our forest networks as possible, we contacted each headquarters and district and confirmed or obtained names of personnel. In most cases, we were able to obtain personnel, but not contact information. We then used the USFS employee search website,[6] which allowed searches for individual employee phone, email contacts by name and Forest, and identified 747 individuals across our USFS sample.

2.4.5. Triangulation: confirming network boundaries and rosters with key informants

Once we compiled information on relevant jurisdictions, organizations, and positions within them using our spatio-ecological, nominal, and positional approaches, we confirmed and corrected our data using a realist strategy of evaluating our decisions in consultation with key informants in each jurisdiction. After completing the network rosters, we conducted telephone interviews with county emergency managers in each county and FMOs in each USFS district. We interviewed 134 FMOs (98% response rate) and 98 emergency managers (89%) at least once and consulted many of them on multiple occasions throughout the study. Initial phone interviews elicited descriptive information on wildfire planning, preparedness, response, and coordination activities that we did not have to duplicate in surveys of the larger sample.

In the pre-fire survey, we collected data on responder network capacity and social networks prior to the 2013 fire season for all responders identified in our four-state region. Importantly, we asked key informants (FMOs and emergency managers) to complete a paper version of our pre-fire network survey to pilot the instrument. While completing this survey, we asked respondents to correct any names of individuals in the positions listed and to suggest additions and deletions. This strategy proved judicious, as there were dozens of instances where our information was incorrect or out-of-date and we were therefore able to correct our rosters before launching our pre-fire survey with the entire sample.

2.4.6. Design and launch of the pre-fire survey

Once the challenge of determining network boundaries and rosters have been met, network elicitation tools commonly entail significant respondent burden [33]. Our data collection for network rosters used the positional (listing network alters for respondents) rather than the nomination (asking respondents to recall alters in a network) method, as the former helped reduce respondent burden and minimize recall issues (see Refs. [17,34]; 74). The pre-fire network survey was designed to determine whether there were pre-existing personal relationships between respondents and alters in the network (relational embeddedness) and whether these ties were perceived as reliable sources of support. Each respondent received an email invitation to a customized online survey with local, county, and USFS networks based on the adjacency matrix (USFS districts and adjacent counties) of which they were a part. We report response rates for pre-fire surveys in Table 2.

For each alter, we asked respondents whether they knew the individual personally (i.e., interacted on multiple occasions in personal or professional settings) and then to indicate whether they were confident the alter would go out of their way to assist them if a wildfire occurred in the area. Additionally, we were interested in the roles of bridging actors—individuals who connect dissimilar and/or disconnected subnetworks [35]—and therefore employed a complementary nomination approach to eliciting data on individuals preferred as bridges in local networks. We asked respondents to name any individual or role (e.g., sheriff, county commissioner, district ranger) that they would trust to play a role as a community liaison with an Incident Management Team (IMT),[7] should an incident arise.

[5] We buttressed this approach by asking key-informants the following question: if a fire ignited on USFS land and threatened a population center in [county name], what organizations likely comprise the network that would need to be activated to respond?.

[6] http://www.fs.fed.us/about-agency/contact-us/employee-search.

[7] An Incident Management Team, or IMT, provides management support for a disaster incident or an event that exceeds the capacity of the jurisdiction or organization that initially responds, and is usually delegated authority to make decisions about the event they are managing. Federal IMTs coordinate responses to disasters such as wildfires as well as terrorist incidents, public health emergencies, and transportation accidents, and are internally hierarchical structures with pre-assigned roles and responsibilities for their command and general staff and for support personnel.

Table 2
Pre-fire survey sample frame and response rates.

	Organization Level			Person Level		
	Sample #	Response #	Response %	Sample #	Response #	Response %
Local Organizations	1432	654	49%	1784 [1781[a]]	770	43%
USFS Districts	137	137	100%	501	395	79%
USFS Headquarters	33	33	100%	246	175	71%
Overall	1613	824	51%	2531 [2528[a]]	1340	53%

[a] This figure refers to the number of *unique* individuals in the sample. This is less than the total of positions in the sample because some individuals held more than one position.

Importantly, in addition to answering network-based research questions (e.g., do pre-fire network structures predict incident response network structures?), we asked several questions about disaster preparedness and respondent attitudes that could help us both explain network patterns and test associations between network variables and preparedness.[8] Thus, along with the network questions, we asked respondents to answer a number of background questions (e.g., age, education, organization size). We also asked questions on other topics of theoretical interest to the study, including: engagement in disaster preparedness activities, the readiness and capacity of responding organizations in their jurisdiction, the commitment of resources to preparedness within their organization, personal connections to place, attitudes toward collaboration, trust in government, and their familiarity with incident command systems and IMTs. The result was a survey with an average length of twelve standard pages (not counting introduction, informed consent, and thank you) that required an average of 45 min to complete.

3. Part II: event-based networks for wildfire response

In this second part, we document an event-based boundary and roster identification process[9] and how we integrated our data from phases I and II. Our intention was to compare structural variables for both individuals and their corresponding organizations in the wildfire response networks across several levels of analysis (e.g., dyadic, node, subgroup, whole network) in the pre-fire and event-based networks. For instance, low network density and/or isolated nodes could reveal important gaps in communication and coordination, whereas high density might indicate overload and inefficient communication burdens. High centralization could indicate network vulnerability due to overreliance on one or a few key individuals to connect subgroups. Identifying components and subgroups could aid in efforts to connect disconnected network portions. This would also allow for the investigation of whether relationships between two actors (dyads) prior to and during the fire were related to overall performance in disaster response, which was measured using a separate measure developed and validated specifically for this study [9][10]. Alternatively, this would enable us to determine whether pre-fire node centrality is related to node centrality during an event. To our knowledge, this is the first dataset of its kind to explore pre-event and event-based response.

3.1. *Whole network boundaries revisited: event boundaries*

As emergent networks in disaster response are neither independent of nor fully prescribed by pre-event patterns of interaction [22], it is challenging to untangle which aspects of network interactions are pre-existing and which are truly emergent. Conceptually, this supports a longitudinal strategy. Over the course of this ongoing, longitudinal project, we discovered that the processes of detecting and collecting data on pre-existing and emergent networks of interaction are not matters of singular theoretical or methodological judgments. Researchers must make multiple decisions about combinations of theoretical direction and empirical data collection that complement each other to serve the research questions posed. This second phase of our study relied primarily on an *event-based* approach to determining network boundaries. Because two critical (of many) potential outcomes of emergent response networks are that they may be fragmented with isolated subgroups or contain latent connections that elude direct observation, one key strategy is to develop a hybrid data collection approach. This required employing a nominal approach, relying upon theoretical boundaries, and eliciting network composition based on inclusion criteria specified by the researcher (see Refs. [18,20]).

3.2. *Inter-organizational and social network analyses: furthering the synthesis*

An organization's position in a network can have direct implications for opportunities and constraints on action [20,36], but in emergent disaster response networks, opportunities and constraints in one area of the network can cascade throughout the network and shape the emergent structure [22]. As with any sociological construct, we must define networks to maximize comparability across organizations, and so that scholars can make a sensible argument for why their bounding strategy is theoretically meaningful [16].

Mason Carpenter and colleagues [5] sketched important operative distinctions between studying interpersonal or inter-organizational networks as causes or consequences; they can be studied as contexts for understanding actions of actors and network behavior itself. For instance, social capital research might use network constructs as independent variables, while the same variables might serve as dependent variables in network development studies. Carpenter and colleagues ([5]; 1330) also pointed to “intrinsic differences between individuals and organizations,” as well as studies where inter-organizational networks have been operationalized by identifying the networks and network resources of top executives (see also [37]).

[8] Preparedness activities included items like adoption of a Community Wildfire Protection Plan or inclusion as a signatory of a memorandum of understanding with another jurisdiction, along with questions about other jurisdictions or agencies involved in the agreement, and when official agreements were last updated.

[9] In this article, we use the terms “event” and “incident” interchangeably, as the accepted term for the methodology is “event-based,” while the disaster response idiom employs the term “incident.” We use these terms in explaining our methodology, while recognizing that disasters are not properly regarded as events, but rather as processes [42].

[10] Building on the work of Mandell and Keast [43] and Turrini and colleagues [44]; we employed a pluralist and multilevel approach to collecting and analyzing network performance indicators across five domains (5-point Likert scales) of functional outcomes dependent on network coordination (evacuation, 6 items; coordination and response, 9 items; sheltering and mass care, 5 items; public information, 4 items; and road closure, 3 items). We then used hierarchical linear modeling to measure within-network and between-network variation across all incidents in our sample.

Table 3
Iterative stages of event-based network bounding & detection: Approach, method, data, & triangulation.

Network Bounding Approach	Method of Detection	Data	Triangulation
event-based	Identifying parties involved in specific incidents (wildfire response networks)	Identify incidents within sample boundaries & determine jurisdictions and organizations involved using incident reports and pre-incident network rosters	Confirm network actors with key informants in core event liaison roles

When the network phenomenon of interest is social (e.g., information sharing, coordination, communication), inter-organizational networks often operate and exist *through* interpersonal interactions that span organizational boundaries. Under these circumstances, the distinction between inter-organizational and interpersonal networks is not always definitive, leaving the researcher with a series of design challenges. One option is to collect network data from every member of every organization represented in the network. The sheer immensity and unfeasibility of this approach generally makes it a non-starter. However, even if it were feasible, this approach is still problematic, as it is likely to misrepresent the network in important ways.

We would not expect *every* member of an organization to have an externally facing role in which they would directly interact with representatives of other organizations on behalf of their organization. Therefore, if there is no expectation that they would have externally facing ties, it is not theoretically meaningful when an actor has no such ties. Further, this problem will not affect all organizations of the network uniformly, as some (e.g., larger) organizations are likely to have more internally focused individuals. Consequently, network metrics based on analysis of all representatives of all organizations would bias downward for organizations with more members for whom external connection is irrelevant to their jobs. In wildfires, it is standard practice for responding organizations to assign one or two leaders to serve as the primary liaison(s) responsible for communication and coordination with all other organizations in the incident response network. This individual becomes the de facto face and voice of that organization within the network. Yet, at the same time, research has found that the networking behavior of agents during a disaster is strongly influenced by embeddedness of pre-existing social networks that they carry as an individual [22]. Our study builds upon these insights by tracing the ties between organizational leaders as viable proxies for inter-organizational ties.

3.3. Event-based network boundaries and rosters

To identify emergent networks involved in wildfire response, we relied on event-based detections of parties to specific wildfire response networks. Having established pre-event network boundaries and rosters, our team had to work strategically and often quite rapidly during the summer 2013 wildfire season to build networks of agencies and personnel based on emergent processes of large wildfire response operations that took place within our pre-fire sample region (see Table 3). The process we came to call “fire watching” entailed monitoring wildfire incident reporting websites, contacting and interviewing IMT leaders on events that met our selection criteria, and completing our network by confirming contacts with key informants on the fire.

3.3.1. Fire watching: incident tracking and selection

To identify incidents occurring within our sample area and which met our search criteria, we conducted daily online wildfire monitoring—"fire watching"—between May and September of 2013. Because our focus was on the ways inter-organizational relationships influenced preparedness for, and responses to, large scale wildfires, we established incident inclusion criteria that would ensure we identified large and relatively complex wildfires that involved the greatest cross-section of responding agencies, jurisdictions, and scale (local, state, and federal). Because our pre-fire sample focused on local and USFS networks, one basic event selection criterion was that fires must have either started on or spread onto USFS land. In addition, they had to meet at least three of the following four criteria: 1) federally or state certified Type I or Type II IMT assigned; 2) significant values-at-risk, including threatened residences (not just biological values or outbuildings); 3) evacuations or road closures in effect; and 4) involves multiple jurisdictions in response operations. In the end, we included 21 large wildfire incidents (Type I or Type II) in our event-based sample.

To ascertain whether fires met our criteria, our team checked National Interagency Fire Center reports[11] for new large fires in the Northwest (which includes Washington and Oregon), Eastern Great Basin (southern Idaho), and Northern Rockies (northern Idaho and Montana) regions each day. We then checked InciWeb,[12] an all-risk incident information system operated by the National Wildfire Coordinating Group. InciWeb provided additional, detailed information about ongoing wildfires, including affected jurisdictions (county, state, and federal), values at risk, area burned, agency administrators (i.e., agencies who call in IMTs and share incident command), and the IMT assigned. We then consulted the Geographic Area Coordination Centers website[13] to make sure the information about resources available in the Northwest, Eastern Great Basin, and Northern Rockies regions matched National Interagency Fire Center information.[14] The fourth critical step entailed logging into the National Fire and Aviation Management website and downloading Event Status Reports (ICS-209) for current fires of interest. We then used details from these reports to track the IMTs assigned to each fire, percent containment, and other basic data on the fires. These criteria resulted in the selection of six Type I and fifteen Type II incidents for our sample.

3.3.2. Network identification: building event-based network rosters

Once we identified incidents meeting our criteria, we had to move quickly to build our network rosters while the fires were still active in order to minimize problems with informant recall (see Ref. [38]). Incident reports revealed what jurisdictions (National Forest, county, or municipality) were affected, which allowed us to anticipate what agencies and positions (e.g., sheriffs, county commissioners, fire departments) were likely involved; however, we needed to confirm this information and find out what other organizations (e.g., Red Cross, animal rescue) were involved. For this, we transitioned from our initial event-based approach to working with key informants in a realist strategy to confirm what organizations and individuals were present during response operations.

When we identified an incident meeting our criteria during the 2013 wildfire season, we then contacted Incident Commanders to ask for permission to interview their team, obtain contact information for key members of their command and general staff,[15] and to confirm jurisdictions involved. In several instances, we found that jurisdictions

[11] https://www.nifc.gov/fireInfo/fireInfo_main.html.
[12] http://inciweb.nwcg.gov/.
[13] https://gacc.nifc.gov/.
[14] This was primarily used to gauge whether smaller fires may require a Type I or II team because of in-region resource scarcity.
[15] Deputy Incident Commander, Public Information Officer, Operations Sections Chief, and Liaison Officer.

Table 4
Event-based survey sample frame and response rates.

	Organization Level			Person Level		
	Sample #	Response #	Response %	Sample #	Response #	Response %
Local Organizations	249	120	48%	446	167	37%
USFS Districts	34	31	91%	123	76	62%
USFS Headquarters	19	17	100%	152	81	53%
Other Host Agencies	14	10	71%	53	26	49%
Incident Management Teams (IMTs)	19	19	100%	109	104	95%
Overall	333	197	59%	982	456	46%

*This figure refers to the number of *unique* individuals in the sample. This is less than the total of positions in the sample because some individuals held more than one position.

listed on Incident Status Reports were not reliable indicators of the jurisdictions actually mobilized for the fires. At times, reports listed a given county because it bordered the National Forest district that was ablaze, but the fire had not breached any geographic thresholds ("trigger points" in the Incident Command idiom) that warranted the mobilization of a named jurisdiction. Representatives of agencies from that jurisdiction were on call to receive regular updates and mobilize, if necessary; in lieu of this, we eliminated these jurisdictions from our models.

Timing was critical in contacting Incident Commanders during ongoing wildfires. If we contacted them too soon, we risked interfering with fire management. If we waited too long, there was a chance that an IMT could transfer command and move on to another incident. Our initial criterion was that we would wait until an incident was at least 60% contained, meaning that operations would begin winding down, but it would be unlikely that IMTs were transitioning. After one Type I IMT transitioned to another incident shortly after 50% containment, and prior to our contacting them, we lowered our threshold to 50%.

Though our approach to identifying incidents and jurisdictions was generally consistent with event-based strategies, we relied on key informant nominations to determine which agencies and individuals were involved with each incident. After speaking with an Incident Commander, we contacted the Liaison Officer or equivalent (sometimes the Deputy Incident Commander or Public Information Officer) for the IMT. The primary responsibility of a Liaison Officer is to handle day-to-day coordination with local, state, and federal cooperating agencies, and so we recruited them as ideal candidates to confirm the agencies and personnel engaged as cooperators in response to the incident and to add additional actors and agencies that were involved, but not listed, in our pre-fire rosters. We read our list of agencies and personnel from the affected jurisdictions and Liaison Officers confirmed which agencies were involved and which should have been involved. In several cases, agency personnel had changed (e.g., newly elected sheriff, retired District Ranger), so we had to update our rosters in real time. In many cases, Liaison Officers were able to provide reliable contact information for agency personnel. We further confirmed response network information through triangulation with phone calls to select responding county agencies and host units (USFS FMOs, emergency managers, or county sheriff). Thus, we did not solely rely upon our previous spatio-ecological boundaries, incident boundaries, or rosters previously developed using nominal-positional strategies. Just as in the pre-fire phase of the project, we found it was essential to include realist confirmations of our network identification strategies to capture data on evolving and emergent networks; to ensure that we documented who *actually* participated in the network, not only who theoretically might have. We report the total agencies, units, and individuals identified in the process in Table 4.

Because our focus was on communication networks, we elected in the event-based phase to base the network rosters on individuals assigned as lead liaison(s) for their unit/organization. This allowed for the creation of a one mode, person-to-person network based on unit leadership rather than a two-mode, person-to-organization network. As with all approaches, there were advantages and disadvantages to this design. The advantage lies in the theoretical clarity of the network under investigation. While communication undoubtedly occurred across organizational boundaries among other individuals—it was the leadership network that was of greatest theoretical interest in this study.[16]

3.3.3. Design and launch of the event-based survey

After confirming actor participation with Liaison Officers, we launched our event-based survey in two waves. We first contacted each of the IMT personnel in our sample and administered the survey to them over the phone before they rotated onto another incident. We then emailed invitations[17] to all other respondents to complete a customized web-based survey based on the event-based networks (see Table 4 for response rates). While our response rates overall were quite high for survey research, there was variability across groups. Most notably, we had the greatest difficulty obtaining participation from local agencies. The principal investigators on this initiative have worked in the domain of wildfire and with federal land agencies for many years, allowing us greater legitimacy among the federal agencies than the local agencies. We therefore feel that relationship building in the study areas is likely to increase future response rates.

In the network portion of the survey, we asked respondents to indicate their frequency of interaction with host agency/unit personnel identified in the incident response network and to indicate how much room for improvement there was in these interactions on a 5-point Likert scale (network performance). We also repeated our nomination approach to identifying network bridges from the pre-fire survey to compare pre-fire patterns in trusted network bridges to actual network bridges in the incidents (see Ref. [35]). We asked respondents an open-ended question to nominate any individuals or roles (e.g., sheriff, county commissioner, district ranger) that were particularly helpful in working effectively with an IMT; or to nominate those who took leadership roles in helping to maintain effective communication and coordination among the different agencies/organizations involved in response.

In addition to the network questions, the survey included multiple questions regarding several incident-based topics (see Ref. [9]), the exchange of assistance between agencies, relational impacts of the fire, respondent connection to place, and general background questions, as in the pre-fire survey. The result was a survey with an average length of

[16] Had we used a two-mode network, it would open the possibility that we would project an inappropriate level of significance to an interaction. For instance, brief interaction between a USFS District Ranger and a deputy officer posted at a road closure is a type of network tie between the USFS District and the county law enforcement. However, it is of a very different theoretical nature than communication that occurs between the USFS District Ranger and the Pine County Sheriff, as this is more likely to entail strategic decision-making.

[17] As with the pre-fire survey.

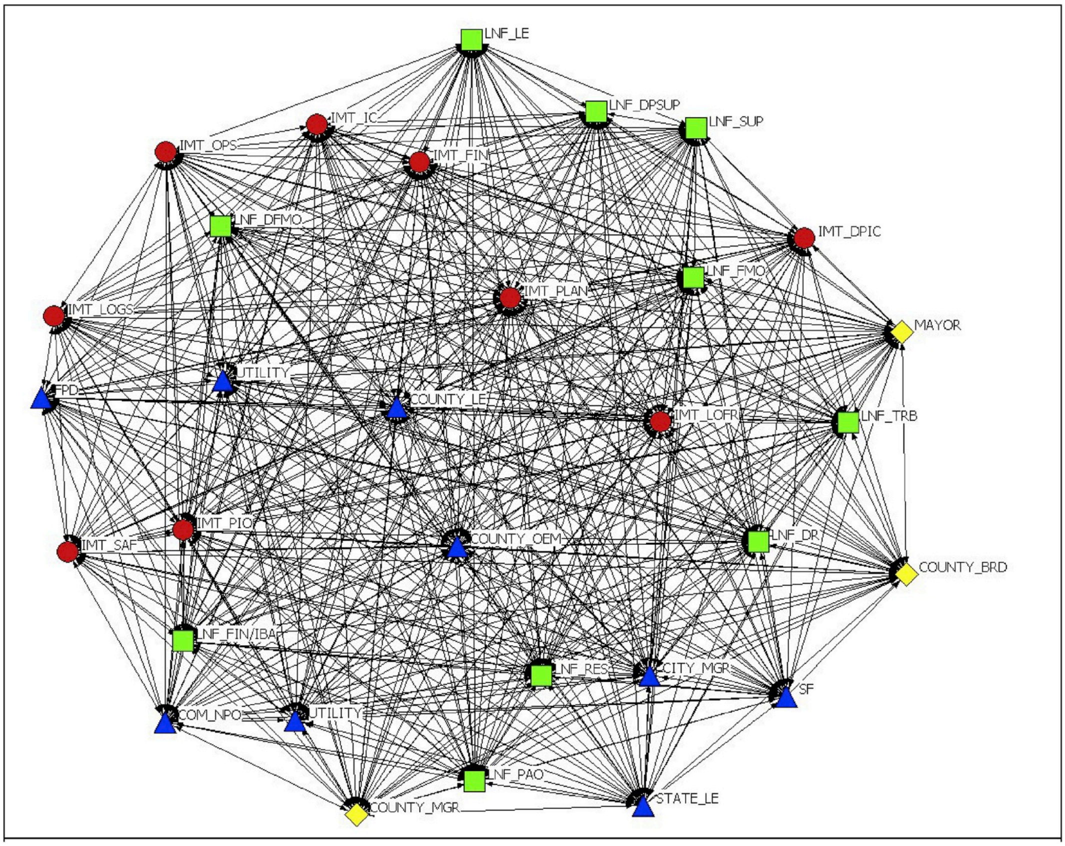

Fig. 1. Incident Response Network during the Rabbit Fire. ■ Local National Forest (LNF), ● Incident Management Team (IMT), ▲ County Emergency Response, ◆ Local, County, and State Government, —— Interaction During Incident.

16 standard pages (not counting introduction, informed consent, and thank you) that required an average of 50 min to complete.

3.4. Variables and data management: tying phases I and II together

In addition to network identification and data collection, this project required investing a significant amount of data management effort. The core of any such strategy necessarily entails creating a robust hierarchical identification system and a process for correcting errors and tracking changes. The identification system we developed enabled us to attach unique identifiers to each individual and to nest them hierarchically and relationally to others with systems of unique identifiers for jurisdictions, organizations, and incidents.

In the pre-fire network identification phase, we assigned unique ID numbers to states, counties, municipalities, organizations, forests, forest districts, and individuals. In cases where we were unable to identify specific individuals in a position (e.g., fire chief), we assigned an ID number to the position as a placeholder. However, anticipating the challenges in tying together the pre-fire and incident-based networks, we made the decision early on to attach ID numbers to people and not just positions, as the specific individuals in a given position might change over time. For example, a given sheriff John Doe would be associated with state ID 1, county ID 22, organization ID 336, and personal ID 6541. Should the individual in that role change, we would only modify the personal ID and all other ID information would remain consistent, enabling us to connect the position of a given agency (and agency leadership) in pre-fire and incident-based networks while also recognizing personnel changes and accounting for the influence this might have on network structure and performance. Thus, the only added identification system in phase two was the addition of an ID for incidents.

Each phase of the process entailed plenty of error correction. Simple spelling corrections and the discovery of new organizations or individuals required a cross-reference of the entire network system (adjacencies and rosters) to ensure that we did not duplicate identification numbers. At times, correcting the spelling of a name or filling in a placeholder position with a new name resulted in the realization that specific individuals appeared in multiple organizations in the network and required a systematic correction of identification numbers throughout the system. An important part of our process was a project log that included details about clarifications in networks, decision rules developed along the way, and each edit to the system. This enabled us to ensure consistency in our decision making (our team grew from two PIs and three students into two PIs, a post-doc, and a dozen students), as well as creating for us a clear record of edits to each identification number and name in the networks. Throughout each phase, we made and detected innumerable errors resulting from dated or faulty public records (e.g., incorrect names or contact information), attrition (e.g., dissolution or administrative combination of agency units, position turnover between T1 and T2), and simple typos and researcher mistakes.

4. Discussion and conclusion

In this article, we have presented our recursive, multi-stage strategies for network identification around the problems of discovering, bounding, and populating pre-existing and emergent networks of individuals and their corresponding organizations in a pre- and post-test design. As revealed through our experience, detecting and collecting network data involved numerous challenges and relied on multiple decisions at different points in time that leveraged specific theoretical and grounded data collection approaches. In the end, responses to roster prompts enabled us to generate standard structural variables for both individuals and their corresponding organizations in incident response networks (see Fig. 1). Longitudinal analysis in the resulting dataset is possible at four levels of analysis: dyadic, node, subgroup, and whole network. For example, dyadic longitudinal questions would include understanding whether the strength of the relationship between any two actors pre-incident improves the quality of interaction during the fire (e.g., Ref. [22]. At the node level, questions such as whether centrality within the network pre-fire increases the likelihood of serving as a network broker during the fire are possible. At the sub-group level, questions such as whether structural cohesion within a subgroup before an incident lead to insularity and reduced interaction with other groups during the incident are paramount. Bridging actor/organization questions allowed us to measure the degree centrality of specific actors, organizations, and organization types (e.g., municipal government, fire service, federal land management) in planning, preparation, and response networks (see Ref. [35]). Finally, incidents where response rates are adequate allow for looking at the structure of the whole network. In these cases, we would define the network as the network activated during the incident and its corresponding structure prior to the incident to maintain a consistent network boundary.

We must also note the limitations in our study results, specifically in terms of response rates and efficiency. Response rates were appreciably lower for local organizations than for USFS and IMTs in both our pre-incident (Table 2) and event-based surveys (Table 4). However, because our strategy entailed extensive triangulation in a process of constant comparison and correction of network actors and interactions at both stages (and in all incidents), we are confident in our redundancy of sources and capture of network *actors* (and, by extension, network *composition*). With that said, we are mindful that we must evaluate our data on network *interaction* and assess the viability of specific analyses (e.g., network performance) or measures (especially centrality, which is particularly vulnerable to missing data) as we study specific incidents where local respondents are underrepresented.

Other scholars have reflected upon the unique response rate challenges associated with attempting to study multiple networks and networks across multiple timepoints (e.g., Ref. [39]). Our study confirmed and expanded upon the depth of these challenges. While our response rates were overall higher than common survey response rates in organizational research [40], they were still problematic for calculating socio-centric metrics in many of our networks. This was despite having used multiple mechanisms for improving participant response. This necessitated more ego-centric and groupwise comparison strategies for analysis. Earlier, we discussed the need to build relationships with responders and agencies in affected jurisdictions (as we have with those in federal agencies). In the weeks and months after our survey closed, we did realize some gains in rapport building with local interlocutors when we circulated our early findings as part of a series of wildfire incident reports and a county wildfire readiness report.[18] This dissemination helped build both trust and interest that could help improve future response rates, as representatives from local agencies that had not responded called to comment on and commend the reports and their utility.

In terms of efficiency, readers will note that this process was labor intensive and time-consuming. The processes that constitute some of the greatest strengths of our approach—triangulation and constant comparison of actor-reported network composition and interaction—were also the most demanding. Because we could know only where fires *might* occur across four states, we wound up collecting network data from 109 counties and 137 USFS districts in the pre-fire survey to capture the range of possibilities, while our post-fire survey involved only 34 districts and 54 counties. Thus, one advantage of the post-hoc approach to studying disaster response is the benefit of knowing where events took place. However, one core concern of ours is to build frameworks with the capacity of understanding pre-emergency preparedness as one aspect of disaster risk reduction. We therefore hope that future studies employing some version of our framework will develop strategies for increased efficiency in network identification and data collection.

We hope this article can contribute to demystifying network data collection for people new to the approach while problematizing some of what we perceive as too-neatly circumscribed assumptions about how to identify and bound real-world networks. We tailored the approaches detailed in this article to the specific objectives and challenges of multi-stage network identification and bounding for pre-existing and emergent networks involved in wildfire response. Though the methods we identify here can clearly prove useful in studying a variety of disaster preparedness and response operations, we see potential for replication with other network problems relevant to disaster risk reduction. The researcher quoted at the beginning of this article was concerned with mapping networks of fishermen before and after policy implementations intended to reduce the risk of fisheries depletion. Other compelling contexts include the broader range of complex issues surrounding disaster response, recovery, and adaptation [6] and the displacement and resettlement of human populations owing to development, disasters, climate change, violent conflict, and conservation [41]. Potential questions in each of the areas include:

How do pre-existing networks provide support for community members (in a given issue area)?
How can a planned [policy implementation, intervention] sustain and foster the development of these networks?
How do networks facilitate or inhibit [fisheries sustainability, community livelihoods]?

The general parameters of our approach entail confronting the challenges of establishing spatial, conceptual, and realist relational boundaries prior to and following an intervention, which can be an event (as in the present case) but may also be a policy implementation or other significant change introduced to a place or population. Each component of our design can be applied independently, or multiple components can be strategically combined.

We are also concerned to address several gaps we see in network studies of disasters and emergency response. While there have been noteworthy advances in studying hierarchical networks in hazard mitigation (e.g. Ref. [10]), our study presents a viable approach to non-hierarchical, emergent response networks. We based our methodology on a theoretical model that posits that response networks are neither entirely determined by, nor fully independent of prior networks. We therefore developed combinations of boundary approaches that work in pre- and post-test designs using spatio-ecological boundaries, nominal-positional strategies, as well as realist approaches at different stages to identify and confirm our networks.

Our approach also complements important methodologies for studying response networks based on document artifacts such as memoranda of understanding and situation reports (e.g., Ref. [25]). Specifically, we learned that collecting data directly from response personnel helped us eliminate organizations, actors, and whole jurisdictions from network samples in Incident Status Reports. This is because they were not actually active on the incident, only named because they *might* be mobilized should the fire cross a defined boundary. Lastly, we endeavored to synthesize social network and inter-organizational network analyses to resolve potential sampling problems (over-sampling agency personnel can distort degree centrality when most personnel are not outward facing). We therefore used agency and unit leaders as proxies for organizations/units in our network samples, creating a parity among organizations varying in size while emphasizing the roles of leaders tasked with liaising with other organizations. Thus, we found that interactions in complex, emergent, inter-organizational networks are nether purely inter-organizational nor interpersonal but can be conceptualized as both.

[18] See https://research.cnr.ncsu.edu/blogs/firechasers/reports/.

A final significant insight that emerges from our work is that accumulated evidence on preparedness and response can identify risk factors in preparedness and planning and inform preparedness network-building initiatives. While single case study work is important, moving beyond single cases and drawing insights and lessons from a larger population of disaster response networks will be critical for advancing social science insights into disaster risk reduction and response. It is therefore paramount that we continue to advance methods for engaging in these more complicated designs.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijdrr.2019.101260.

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