# Tweeting Tsunami:
# Early Warning Networks in British Columbia

**by**

**Amanda Oldring**

B.A. (Hons. Psychology and English), Thompson Rivers University, 2007

Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Arts

in the
School of Communication
Faculty of Communication, Art and Technology



**SIMON FRASER UNIVERSITY**

**Fall 2015**

## Approval

| | |
|---|---|
| **Name:** | **Amanda Oldring** |
| **Degree:** | **Master of Arts (Communication)** |
| **Title:** | ***Tweeting Tsunami: Early Warning Networks in British Columbia*** |
| **Examining Committee:** | **Chair:** Betty Schellenberg<br>Professor |

**Peter Anderson**
Senior Supervisor
Associate Professor

**Peter Chow-White**
Supervisor
Associate Professor

**Gordon Gow**
External Examiner
Associate Professor
Communication and Technology
University of Alberta

**Date Defended/Approved:** December 16, 2015

## Ethics Statement

The author, whose name appears on the title page of this work, has obtained, for the research described in this work, either:

a. human research ethics approval from the Simon Fraser University Office of Research Ethics,

or

b. advance approval of the animal care protocol from the University Animal Care Committee of Simon Fraser University;

or has conducted the research

c. as a co-investigator, collaborator or research assistant in a research project approved in advance,

or

d. as a member of a course approved in advance for minimal risk human research, by the Office of Research Ethics.

A copy of the approval letter has been filed at the Theses Office of the University Library at the time of submission of this thesis or project.

The original application for approval and letter of approval are filed with the relevant offices. Inquiries may be directed to those authorities.

Simon Fraser University Library
Burnaby, British Columbia, Canada

## Abstract

Influential Twitter users can enhance disaster warning by diffusing risk awareness through networks. While Twitter networks are frequently active during disaster warning, little work in social network analysis has been applied to the Pacific Northwest Coast, encapsulating British Columbia in Canada, and Alaska, Washington, Oregon, and California in the United States. This region is vulnerable to tsunamis, and Twitter's speed, reach, and volume could enhance early warning. This thesis locates a 1,932 follower network for @NWS_NTWC, this region's source tsunami warning account. Profile content analysis identifies stakeholders and network analysis describes their interconnections by country, community, influence, and embeddedness. Opinion leaders were identified and surveyed (n=125) on Twitter usage and opinions for tsunami early warning. This mixed methods approach assesses how stakeholders can optimize warnings in Twitter. Key outcomes include a longitudinal baseline, network driven decision-making techniques, and strategies for alerting at-risk coastal areas.

**Keywords**: tsunami early warning; self-reported geolocation; social network analysis; stakeholder content analysis; opinion leader detection and survey; Twitter

This work is for anyone who decides to embark into something unexpected. It is also for those who recognize that every voice, especially the quiet ones, matters, and for those who strive in their own way to help those voices be heard, and to make life just a little bit easier, a little bit better for others all around.

Above all this is for Stephanie, who encouraged me to do and be to the best of my abilities.

# Acknowledgements

I would like to acknowledge my senior supervisor, Peter Anderson, and his project "Improving End-To-End Tsunami Warning for Risk Reduction on Canada's West Coast", for providing the institutional precedent, scholarly framework, and community resources necessary for completing this work. I would equally like to thank my supervisor, Peter Chow-White, and all my colleagues at GeNA Lab, for providing the theoretical inspiration, methodological expertise, and passion for big data and social media that are embedded throughout this project. A special thank you must be extended to my colleagues Olympia Koziatek, for providing the maps, and Maggie MacAuley, for introducing me to NodeXL and network analysis. A thesis can also never be completed without substantial financial support. To this end I would like to thank the donors of the Emergency Preparedness Conference Scholarship in Emergency Communications, the BC Egg Marketing Board, the Simon Fraser University Graduate Student Society, and the School of Communications for seeing merit in my research and acknowledging it with a consistent funding base. I would especially like to acknowledge the School of Communications for its inclusive, interdisciplinary and critical approach to scholarship which is difficult to find, challenging to meet, and utterly rewarding to be a part of. I would never have made it here without any of you. Finally I would like to thank my colleagues and peers at Simon Fraser University, in the Department of Communications and beyond, my family, and good friends, for their understanding, support, and love that kept me inspired along the way and gave me the momentum to complete the marathon that is a Master of Arts degree.

# Table of Contents

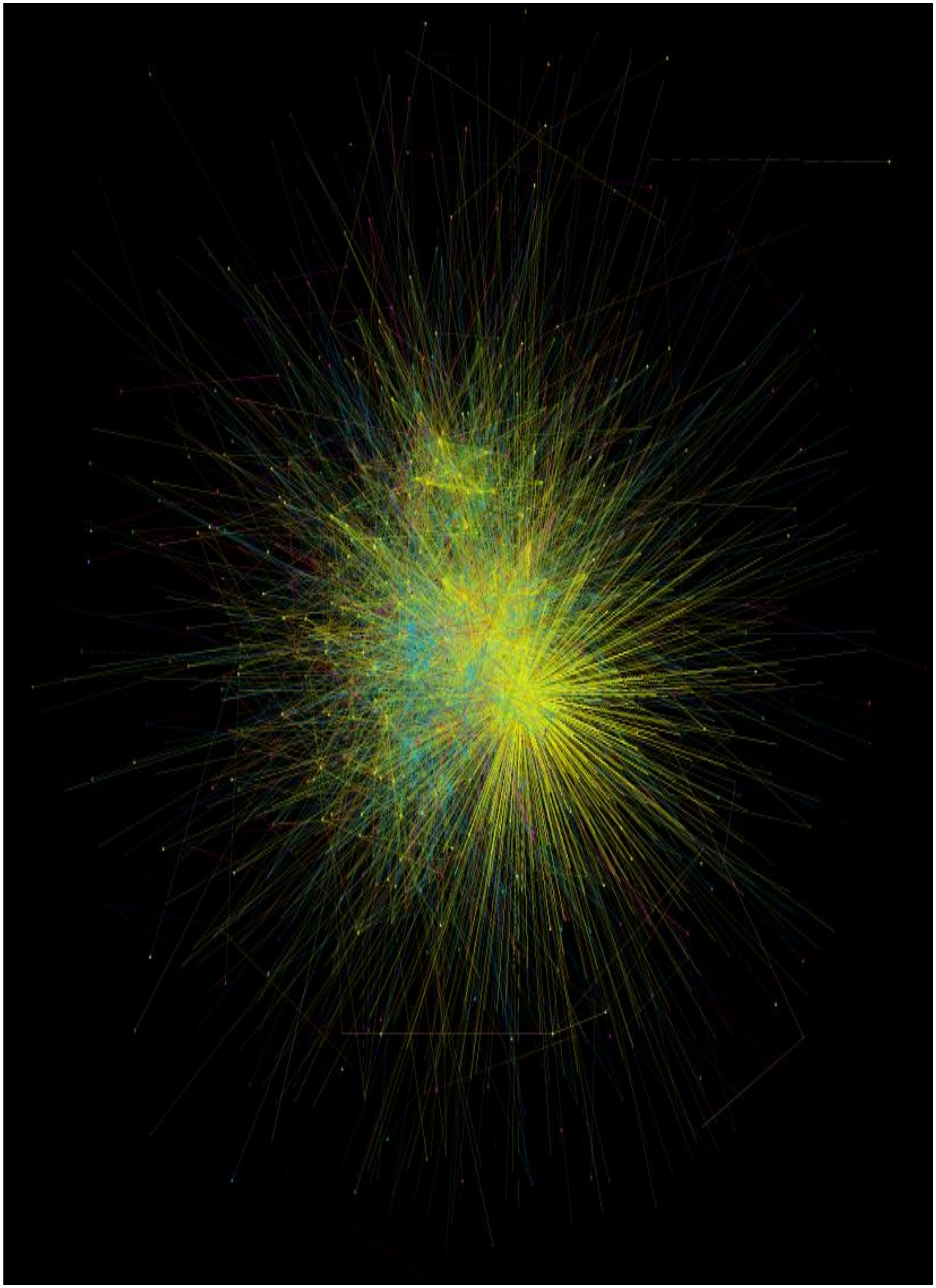
## List of Tables

## List of Figures

## List of Acronyms

| Term | Definition |
|---|---|
| AK | Alaska |
| BC | British Columbia |
| CA | California |
| CAN | Canada |
| CSN | Cascadia Subnetwork |
| DM | Disaster Mitigation |
| EMBC | Emergency Management British Columbia |
| FR | First Response |
| ICT | Information and Communication Technologies |
| M | Magnitude, a metric indicating earthquake size |
| MDT | Media Systems Dependency Theory |
| NOAA | National Oceanic and Atmospheric Association |
| NTWC | The National Tsunami Warning Centre |
| NWS | National Weather Service |
| OR | Oregon |
| PNC | Pacific Northwest Coast |
| SFU | Simon Fraser University |
| SNA | Social Network Analysis |
| US | United States of America |
| VHF | Very High Frequency |
| WA | Washington |
| WRS | World Risk Society |

## Introductory Image: The Cascadia Subnetwork



# Chapter 1.

# Introduction: Tweeting Tsunami

Natural disasters shatter social order. They have foreshadowed civilization since antiquity, inflicting many of history's worst tragedies. Yet, today's disasters differ from those of the past. They are more social, stemming from human-made risks, and more global, creating ripple effects that span decades, surpass borders, and coalesce into new hazards (Beck, 1992). They are more frequent and severe as well (Magrath, 2007). Keeping pace requires communication technologies and strategies that connect people who mitigate catastrophic events. Online social networks are the newest and least understood means of doing so.

In British Columbia (BC), social networks may help mitigate tsunamis. Complex coastlines alongside a seismologically volatile part of the Pacific Ocean necessitate communication systems that warn the right people at the right times. To date, no early warning system in BC is this robust (Anderson, 2015). Outside Canada, social networks have assisted tsunami warning, relief aid, and reporting (Acar & Muraki, 2011; Chatfield & Brajawidaga, 2013). They foster the decentralized, pluralistic decision-making essential to collaborative, emergent disaster response (National Research Council, 2013). By bypassing hierarchies and enabling coalitions, they could support a faster, more coordinated response in BC.

However, little is known about BC's ability to leverage social networks for tsunami warning. As such, this thesis combines social network analysis and user surveys to examine how influence and communication intersect in a tsunami early warning network on Twitter, a platform increasingly valued for disaster mitigation. It situates world risk society (Beck, 1992), media systems dependency (Ball-Rokeach & DeFleur, 1976), social risk amplification (Kasperson & Kasperson, 1996), and diffusion of innovations (Rogers, 2010) theories into an applied-theoretical approach that sheds light on how Twitter networks can prepare for tsunami warnings and find new outcomes to one of the oldest stories ever told.

## 1.1. Rationale

Research addressing Twitter tsunami warning preparedness is rare, and a comprehensive social network analysis (SNA) of BC stakeholders has yet to be achieved. SNA frames problems and potential answers according to human relationships (Marin & Wellman, 2010; Scott, 2013). It provides a window into gauging whether or not Twitter users can reach at-risk areas in BC. Ethnographic surveys can further explain why those users participate in and how they experience Twitter (Rothenberg, 1995). In particular, surveying a network's opinion leaders (OLs), or influential users who prompt others to participate, is a direct path to revealing the social factors precipitating how warnings spread online. This layered mixed methods approach provides insight into how networks are structured to communicate from the top down and how opinion leader behaviors contribute to building that structure from the bottom up, yielding rich findings about warning capacity that are specific to BC and useful for comparative study in other coastal areas.

To date, most related SNA is based on hashtag or keyword networks found during or after an event (Sutton et. al, 2014). Reactive data like this is difficult to acquire in BC because tsunamis are uncommon. Moreover, reactive studies neither reveal preparedness or warning capacity nor indicate which users will participate, which restricts response. In contrast, a pre-event user network can provide disaster management a baseline to assess preparedness and early warning capacity in BC proactively. As such, this thesis uses SNA and OL surveys to present a pre-event warning network for the Pacific Northwest Coast (PNC), consisting of users in BC, Canada (CAN), and Alaska (AK), Washington (WA), Oregon (OR), and California (CA) in the US. This "Cascadia Subnetwork" (CSN) is made up of Twitter users in the PNC who follow the US National Tsunami Warning Centre's (NTWC) account @NWS_NTWC. These users are the front-lines for PNC warning dissemination and the first to see tsunami bulletins enter Twitter. To assess their capacity to warn BC, this study compares CSN stakeholders and the communication lines between them against their proximity to risk. It gauges their last-mile access to rural communities, identifies OLs and particularly weak ties, or OLs who can influence outside the CSN, and examines their perceptions and motives for using Twitter. These data have never been published before and provide a first glimpse into how BC early warning OLs and stakeholder networks are poised to participate in advance of a tsunami.

## 1.2. Theoretical Backbone

In this study, disasters are considered *socially constructed* and *communicated* events. As such, world risk society's sociohistorical context binds the psychological, sociological, and critical communication research that predicates social media's utility in disaster mitigation. Feeding into this premise, media systems dependency, risk amplification, and diffusion of innovations theories explain why disasters elevate Twitter activity and how these networks affect warnings. Twitter's known uses, benefits, and limitations are then addressed and considered within British Columbia's specific warning climate. In particular, opinion leaders are defined as the core mechanism behind warning diffusion in social networks. By extension, the need to identify Twitter based tsunami warning stakeholders, networks, and their opinion leaders in advance of an event emerges as the driving motif behind this work.

Disasters are experienced through mass and now social media (Crowe, 2012; National Research Council, 2013). Mass media are communication technologies that broadcast to large audiences. We know them as print, audio recording, film, radio, television, the Internet, and mobile phones. Information and communication technologies (ICTs) like mass media were once the only way to warn. However, their unidirectional formats limited public participation and truncated information to a few heavily curated sources. Social media are web platforms that facilitate public creation and sharing of user generated content – endlessly reproducible or remixable digital media (Kaplan & Haenlein, 2010; Manovich, 2001). Cheap hardware, mobile device growth, and Internet saturation have ubiquitized social media, dropped entry barriers, shrunk digital divides, and enabled many-to-many communication in real or any time (Flew & Smith, 2011). As creators and disseminators, users form participatory communities over content of interest (Brabham, 2013). By communicating without intermediaries, lay agency has grown and opened backchannels for unfiltered disaster communication in its wake (Sutton et. al, 2008).

Twitter is a free social media service that is Internet, mobile data or SMS accessible on desktops, tablets, and smart and mobile phones. Users follow others ("followers") or are followed ("followees"), and their interactions organize content from the bottom up (Starbird et. al, 2010). They "tweet" in 140 characters or less but can add images, videos, or URLs. Tweets take seconds to make and are posted as events occur (Murthy, 2012). Users also retweet (repeat verbatim citing the author), reply to (nest under), or favourite (archive) tweets. They group tweets with hashtags '#' and identify users with '@' signs. All content is keyword, hashtag, user, or metadata searchable. The result is massive networks of users and bite-sized information that is easy to create, find, view, sort, store, and respond to. Anyone can see or search this data, but only account holders can create it.

These features have spurred widespread adoption of Twitter for communication to mitigate disasters, including early warning (Sutton et. al, 2014). Early warning aims to save lives and livelihoods by providing notice of impending harm (Basher, 2006). Convincing people to act is a matter of influence, or indirectly effecting others' opinions, attitudes, behaviors, or beliefs (Rjad et. al, 1999). Opinion leaders are ordinary people who exert influence with relative consistency. Detecting them is difficult because there is no accepted influence theory for social media. However, theories built for offline behavior can apply to influence online. In particular, social risk amplification and diffusion of innovation's definitions of OL influence resulting from trusted, informal statuses in networks is in line with how warnings spread between people and so apply well to interpersonal communication found in Twitter.

Twitter is also a choice site for tsunami warning research. The site's 288 million monthly userbase, brevity, and convenience foster unprecedented information reach, volume, and speed. It uses geographic data and discrete units of analysis. As Canada's second most popular social network, its sampling population is large (Faber, 2013). Most of all, its event-driven update culture is conducive to disaster communication and to informal conventions that propel idea diffusion (Murthy, 2012). Twitter's (2014) mission, "to give everyone the power to create and share ideas and information instantly", speaks to a communication power shift that relies on publics in a network society to mitigate disasters (Castells, 2008). For these reasons, Twitter offers a window into understanding social networks in relation to tsunami risk, and how OLs are positioned to disseminate warnings within them.

## 1.3. Practical Motivations

Disaster mitigation seeks to prevent, prepare for, respond to, and support recovery from disasters (JIBC, 2010). Disasters can be geophysical (e.g. earthquakes), meteorological (e.g. typhoons), hydrological (e.g. floods), climatological (e.g. wildfires), extraterrestrial (e.g. asteroids), biological (e.g. pandemics), technological (e.g. industrial accidents), or human-caused (e.g. diaspora) (EM-DAT, 2015). Environment, qualities, hazards, and impacts vary but all disasters share a thread of catastrophe that separates them from life's usual upsets. This is the moment a hazard intersects a vulnerable population and seriously harms its safety, health, welfare, property, or environment (Public Safety Canada, 2013).

Tsunamis are enormous wave series that destroy the coastal areas people call home or are sources for their livelihoods, health, or well-being (Anderson, 2006). In BC, tsunamis spur talk of "The Big One", a 9.0M megathrust offshore earthquake due in under 200 years that may cost up to $52 billion in damages (Nasseri, 2014). But, tsunamis are actually common (Clauge et. al, 2003). Twenty-two hit BC between 1997 and 2014 (Anderson, 2015). Their main causes are earthquakes, but shoreline or ocean landslides, volcanoes, or impact events like asteroids can also displace enough water to cause tsunamis (Clauge et. al, 2003). Although BC has sustained only minimal damage in recent history, tsunamis are one of the planet's most destructive forces. The 2004 Indian Ocean Tsunami was due to a 9.0M earthquake. It killed over 225,000 people, displaced 1.7 million in 14 countries, intensified conflicts, destroyed ecosystems and destabilized infrastructure and economies (Athukorala & Resosudarmo, 2005; Hagiwara & Sugiyarto, 2005; United States Geological Survey, 2012). Lack of early warning was a major catalyst (Nova, 2005). That hard experience spurred BC to adopt new ICTs, including Twitter, to improve warning for a similar local event as well as for the frequent tsunamis generated in the Pacific Rim.

Yet, BC's warning systems, processes, and organizations are hierarchical and have many authentication stages. Whenever an earthquake is detected NTWC watchers in Palmer, Alaska activate an automated system, including a web service that runs @NWS_NTWC within three minutes (NTWC personal communication, Dec. 3, 2014). BC's disaster management (DM) branch, Emergency Management BC (EMBC), receives its sensory data and bulletins from NTWC, which causes delays as officials prepare warnings for local contexts. That time is not always available. In 2012, a 7.8M earthquake struck off of Haida Gwaii Island in BC. NTWC issued a tsunami warning almost immediately whereas EMBC issued its first warning by email a full hour later (Anderson, 2015). By that time, NTWC's warning had already found BC publics (Anderson, 2015). British Columbians are social media adepts. As of 2013, 86% had Internet, 85% used a cellphone, and 64% owned a smartphone (Insights West, 2013; Province of British Columbia, 2015b). Most mobile activity was on social media (Canadian Internet Registration Authority, 2014). A Canadian Red Cross (2012) survey also found 66% of users felt first responders should monitor and respond to calls with social media, and 33% believed they already did. When Haida Gwaii shook, expectations for EMBC's social media response were already high, sparking a public outcry at the delay (CBC News, 2012). In response, EMBC revised its notification process, making NTWC the first stop for official warnings in BC. Subsequently, interest in using Twitter to communicate among and between mitigation stakeholder groups in BC has grown (Anderson, 2015).

As such, the core problem this study addressed is interoperability. Interoperability is the ability to flexibly coordinate and collaborate in constantly changing disaster landscapes (Broenner, 2012). It requires integrated technological and social systems, and is one of the biggest challenges to disaster management today. Lack of interoperability due to poor or missed communication within and between stakeholder groups has increased damages or loss of life in some of this century's worst disasters, including the 9/11 attacks, Hurricane Katrina, and the 2010 Haiti earthquake (Broenner, 2012; Comfort & Hasse, 2006; Sharp & Losario, 2011). The term is often applied to first responder device compatibility or need for shared channels. However, there are many barriers to interoperability, many of which emerge from the need to better understand the social underpinnings of why people communicate. Disaster mitigation stakeholders include businesses, first responders, local, national, and international governments and institutions, non-profit and regional organizations, and publics both remote and local to impact areas (Hannigan, 2012). These groups should be able to communicate whenever the need arises. However, duplicated initiatives, limited shared standards or institutional support, information lack or overflow, low readiness to coordinate or collaborate, communication line or infrastructure loss, and failure to understand local conditions impede interoperability (Broenner, 2012; Garnett & Kouzmin, 2007). As Haida Gwaii's case shows, early warning in BC struggles with organizational and technical incompatibilities. Twitter is a potential interoperability bridge, helping dismantle barriers by enabling stakeholders across social strata to communicate directly, and opening new warning avenues that encompass an array of actors and collaboration opportunities. This study's results help clarify whether Twitter networks can realistically resolve these barriers by working together to warn BC's at-risk populations.

## 1.4. Purpose and Scope

This thesis is an empirical social science study. Its purpose is not to prove that social media are poised to mitigate disasters. Neither does it critique applications or methods for tsunami early warning in Twitter. Rather, its theoretical framework establishes a media environment that situates the study and establishes its importance. Its objectives are: 1) identify the CSN, 2) define its stakeholders, 3) detect OLs, and 4) gauge their capacity to warn. In this it offers three contributions. First, it showcases a transparent method for descriptive social network analysis, user profile content analysis, and OL detection that surpasses limitations in the literature. Second, its OL surveys augment the network data and provide new insight into practices and perspectives for disaster communication in Twitter. Third, it assesses the literature's best practices against OLs lived experiences. The findings inform researchers and practitioners alike on how Twitter can best support tsunami warning in BC, identifying areas that work well and those that need improvement.

Ahead, Chapter 2's literature review overviews the study's core theories, situates disasters as communicated events, and contextualizes Twitter warning for BC. Chapter 3 lays out the social network analysis, content analysis, and survey design and methods, providing schematics for a pre-event network snapshot and its' population, sampling procedure, and sample. Chapter 4 lays out the social network analysis findings. It maps stakeholders across the CSN to determine their roles relative to risk, focusing on rural and group communication structures. Chapter 5 details the OL survey responses. It compares these to CSN data to test the network analysis' validity. Focus is on how OLs engage Twitter, their thoughts about its benefits and limitations for disaster communication, hashtag and content management preferences, and recommendations for improvement. These are cross-examined by stakeholder group, community type (rural or urban), coastal access, and connectedness (strong or weak ties). Chapter 6 concludes by examining how the CSN best assists tsunami warning in BC by comparing these findings to best practices in the literature, and recommends ways to enrich BC's warning capacity. Chapter 7 concludes by reviewing key findings in the context of applied future directions, and in light of these invites readers to adopt Twitter as more than an echo chamber for the trivial or banal, but as a legitimate and interoperable communication system based on human connection, public participation, and personal investment.

# Chapter 2.

# Literature Review: Disaster are Social

This literature review establishes grounds for defining disasters as communicated events. These encapsulate the interplay of media systems, interpersonal communication, and intersubjective assessments that underlie risk interpretation in a networked society. In this framework, world risk society (Beck, 1992, 2006) is explored as a mode of organization that sensitizes people to and drives the modern rise of public witnessing and participation in disasters from local to global scales. Media systems dependency (Ball-Rokeach & DeFleur, 1976) is then discussed as a key reason why public use of social media during disasters is conducive to early warning. Social risk amplification is explored next as the ability of informal opinion leaders to influence risk perceptions, and diffusion of innovations is discussed as the means for perceptions to spread using social networks (Kasperson & Kasperson, 1996; Rogers, 2010). The two influence theories paint a process wherein opinion leaders leverage social networks to disseminate warnings, and so are an update and distribution mechanism. In combination, these four theories provide a foundation for Twitter as a platform both utilized by and that shapes communication to mitigate disasters. A founding concept that emerges is that social media make difficult collaborations between and within stakeholder groups more commonplace. This role is examined in light of current research on Twitter as it relates to tsunami warning and to risk in BC.

## 2.1. Disasters as Communicated Events

The term *natural disaster* is a misnomer. In 2010, a 7.0M earthquake killed over 225,000 people in Haiti. It was twice as deadly as any similar event in the last century and more lethal than an 8.8M quake that same year in Chile (Pinto, 2010). The disproportion was due to entrenched socioeconomic vulnerability. Weak institutions and infrastructure cut by a food crisis and political instability markedly amplified damages (Hou & Shi, 2011). Surging violence, crime, and insecurity exacerbated inequality, eroded coping ability, and increased hazard exposure, leaving Haiti susceptible to harm (Kolbe et. al, 2010; United Nations, 2008). This case is not unique. Both Hurricane Katrina and the Indian Ocean

Tsunami had similar outcomes (Smith, 2006). Disasters disrupt travel, information and resource streams (Gassenbner et. al, 2010; World Economic Forum, 2014). Sociopolitical turbulence, poverty, inequality, and climate change worsen disaster resilience (Smith, 2006; United Nations, 2004). Disasters are also costly, time consuming, and impossible to fully repair, making future events more likely (Beck, 1992; Chhotray & Few, 2012).

Ergo, disasters are social. They are yoked to modernization processes that hold people responsible and accountable. It is myopic to say people bear all fault when natural hazards are uncontrollable. For instance, in 1986 a carbon monoxide bubble released from Nyos Lake, Cameroon killed 1,700 people (Blaikie et. al, 2014). It was the first geophysical mass asphyxiation recorded and was entirely unanticipated. Thus, human responsibility, liability, and vulnerability must be seen as nuanced and complex. Still, as malefactors in human misery, disaster determinants, experiences, and outcomes are highly social (Blaikie et. al, 2014; Hartman & Squires, 2006). They require system failure to be considered disastrous. An earthquake that does no damage is unremarkable. It is collapse, as when cities buckle or levees fail, which forms this experience. In Dombrowsky's words, "the effects are what we call a disaster" (1995: 244). Destruction creates in-zones where impacted people exist and out-zones where everyone else belongs, with each its own actors and agendas (Hannigan, 2012). In doing so, disasters are tautological flags that define a problem by our ability to solve it (Dombrowsky, 1995): governments declare them to initiate states of emergency, the Red Cross hinges on them to provide aid. Consequently, their mitigation phases (prevention, preparedness, response and recovery) are not positivist but akin to Weberian ideal types, or ultimate projections of what they are imagined to be (Quarantelli, 1998). In this way, disasters are intersubjective realities formed around hazards using collective meaning-making practices, which makes communication a core component.

Carey's (2009) ritual model sees communication, human or mediated, as the construction of a symbolic reality shared by a culture or community. In it, communication is the transfer of information, ideas, and values to foster collective understanding. Traditionally, disaster management uses a transmission model that reduces communication to sending or receiving information (Cottle, 2011). Transmission fits DM as an applied rather than social science, but assumes understanding results from clarity and not interpretation (Chandler, 1994; Quarentelli, 1994). Uprooting transmission from ritual communication's social and cultural bedrock is dangerous. During Hurricane Katrina, unreasonable action advice, lack of expert coordination, and limited public dialogue led residents to believe warnings lacked credibility, causing many to be unaware of the storm or to not take avoidant action (Cole & Fellows, 2008). The 1,833 deaths that followed are certainly tied to this disconnect.

Ritual communication is used to make sense of and give meaning to a shared experience. It creates a disaster *as we know it*, which is why Bergman and colleagues (2010: para.1) expound disasters are “constituted through communicative practices alone”. In particular, the ways media systems signal, symbolize, silence or spectacularize disasters determines their form (Cottle, 2014). The news disproportionately and increasingly covers rare events (Calhoun, 2010; Pannti et. al, 2012). Most stories ignore social precursors, preparedness, and long-standing risk or hazard buildup. Instead an immediate crisis focus, which Pannti and colleagues (2012) refer to as a “calculus of death”, has launched disasters into media spectacle, or as in Hurricane Katrina, megaspectacles that become defining moments of a culture (Kellner, 2010). In doing so media spur overarching metanarratives that establish a disaster’s social significance.

Disasters belong to a different genre than political or sport spectacles because they are not prepared in advance and are disruptive instead of ceremonial (Katz & Liebes, 2007). Like all spectacles, they reflect cultural identity and legitimate political power (Hannigan, 2012, Kellner, 2010). However, they do so uniquely by justifying restorative interventions that permit new and current actors to occupy, alter, interfere with or participate in the social spaces disasters create (Adam et. al, 2000; Dombrowsky, 1995; Hannigan, 2012). A large body of literature indicates disaster response is politically motivated (Hannigan, 2012). US federal disaster funding, for instance, has been unevenly allocated to politically important states (Garrett & Sobel, 2003). Media justify these interventions or lack thereof. For instance, Western coverage of Fukushima Daiichi’s nuclear meltdown stressed world economic impacts by narrowing Japan’s experience as stoicism, so providing a rationale for limited aid (Pannti et. al, 2012). By pressing disaster narratives through domestic filters like economic impacts, media stories resonate with and bolster cultural or state interests.

Increased limelight also ties public disaster comprehension to media (Pannti et. al, 2012). Media shape disasters and their relevance to public interest and involvement because issue coverage or framing correlate to perceived importance, a mechanism called agenda setting (Scheufele & Tewksbury, 2007). For example, the news generalizes disasters into interchangeable stock narratives that compel international communities to witness and assist (Calhoun, 2010). Small or complex disasters can fail to get coverage in the wake of large or domestic events (Pannti et. al, 2012; Vasterman et. al, 2005). Coverage correlates to an event's geographic and cultural proximity (Hannigan, 2012; Pannti et. al, 2012). The 2010 Haitian earthquake was covered by US media for months while the Pakistan floods that year quickly faded to obscurity (Hannigan, 2012). In other words, although individual stories vary, disaster coverage and framing result from the priorities of those who tell their stories (Hannigan, 2012 Pannti et. al, 2012). As such, media industries convey information to publics that is encoded with and reiterates dominant social, cultural, and political mores. No content is innocent, and so too is no interpretation free from embedded bias.

Agenda setting also effects early warning. For example, increased disaster impact news raises warning system procurement priority in US public policy (Collins & Kapucu, 2008). During actual emergencies, media dramatize or de-centralize content from facts to exaggerate or downplay risk, and lay responses to personal or immediate and general or distant frames differ in tandem (Gore et. al, 2005; Miles & Morse, 2006; Wahlberg & Sjoberg, 2000). Usually, undisclosed or low risk is tolerated while high risk is acted on regardless of accuracy (Glick, 2007; Vasterman et. al, 2005). For instance, frequent and detail rich warnings prompt more protective action even if an area's objective risk is lower than its neighbour's (Mileti & O'Brian, 1992). Thus, an argument can be made that agenda setting feeds public warning visibility, reception, and response by shaping risk salience.

Warnings alone are not enough; to act, people must perceive risk. Here, mass media are not the only voices at the table. Risk responses vary by many technical and social factors, including hazard exposure, age, gender, education, socioeconomic status, characteristics of information like frequency, repetition, or source, and personal network composition and feedback (Mileti & O'Brian, 1992; Dash & Gladwin, 2007). As such, public response results from a combination of assessed risk, information received, and personal character (Mileti & O'Brian, 1992). Mass media have a powerful role in framing risk visibility and narratives; the news is actually better at sparking evacuations than official warnings (Dash & Gladwin, 2007). However, witnessed behavior and information from neighbours, family, friends, or peers are even more so (Dash & Gladwin, 2007). Thus, efficacy must be considered in light of all communication networks publics use to acquire and process warnings. These include mass media but also ICTs, the Internet, and professional and personal networks, with social media as a new addition (Kasperson & Kasperson, 1996). Perception is deeply social, so interpretation relies on ritual communication that media facilitate.

Warning perception follows a hear-confirm-understand-believe-personalize sequence (Mileti & O'Brian,1992). Lay people use affect heuristics, emotional judgements, to assess and respond to imminent risk (Finucane et. al, 2000; Keller, et. al, 2006; Marx et. al, 2007; Slovic et. al, 2005). As a result, confirming risk is a struggle to find and process information quickly enough to make decisions, and experts can be relied on with elevated confidence (Dash & Gladwin; Lupton, 2013). As such, how trusted sources present risk alters its reception (Kasperson et al., 1988; Lupton, 2013). These can be anyone knowledgeable about risk, like academics, eye witnesses, or local authorities. For example, expert support from victims, lawyers, and advocacy groups in news coverage of 1992's Biljmermeer plane crash correlated to mass doctor's office visits for symptoms related to chemicals publicized to be on the plane but were not significantly present (Vasterman et. al, 2005). In this way, interpretation is based not only on what is said, but also who has said it, and broadcasting expert opinion taps into social processes like trust that make intangible risks believable.

At the same time, interpersonal communication between people facilitates sense-making and opinion formation about expert information (Erbring et. al, 1980). Lay people discuss risk to interpret urgency and to gauge likelihoods against their and others' assessments (Lupton, 2013; Kahneman & Tversky, 1972). Which information they share and base decisions on is filtered by their assessments, demographics, knowledge, and experience, as well as collective memory garnered from mass media and community history (Dash & Gladwin, 2007; Lupton, 2013). For example, in the case of early warning where damage has yet to occur, involvement in emergency response improves protective action because those networks often discuss risk (Mileti & O'Brian, 1992). Communication in personal networks is so vital a part to warning perception that incongruent messages from outside sources can and have been, as shown during the warning response to Hurricane Katrina, openly ignored (Cole & Fellows, 2008; Dash & Gladwin, 2007). Thus, networks are crucial sources for understanding, believing, and personalizing warnings and risk.

Ergo, mainstream media and spectacles shape risk, expand expert reach, and expedite warnings while interpersonal communication consolidates information and helps people interpret it within social contexts that predicate action. For instance, the news introduces hurricane risk, but social conditions like household composition and communication with others predicts if publics heed evacuation warnings (Dash & Gladwin, 2007). Interpersonal communication can be mediated through ICTs like telecommunications or the Internet, or be face-to-face. What is more important is mutual exchange, particularly between close affiliations, and especially with informal opinion leaders, trusted sources whom lay people personally access (Kasperson & Kasperson, 1996). In this way, integrated networks of people and media underlie warning perception. Only in the last twenty years, arguably since the Kasperson's (1996) work on social risk amplification, have networks come to the fore as mediums for warning spread and decision making. Social media are the newest of these spaces where media, public, and interpersonal communication networks intersect.

Social media foster a physical sense of 'being there' that involves increasingly varied audiences in disasters (Pannti et. al, 2012). Users produce, monitor, update, and regulate content (Albrechtslund, 2008; Sutton et. al, 2008). Organizations work with them and their data to make decisions and collaborate (Crowe, 2012; Guy et. al, 2010; Hughes & Palen, 2009). As a result, disaster visibility, responsibility, and accountability have been informed and transformed. Haiti 2010 is widely considered a turning point in this regard. Volunteers, survivors, and myriad organizations from multiple countries pioneered collaborative social media applications to aid response, including crowdsourced message translation, mobile device geolocated situational awareness mapping, hospital identification, and survivor locating. The surge of civilian voices at Haiti's mitigation table was unprecedented and shifted the communication onus away from coordinating relief providers to hearing, respecting, and empowering survivors to get and receive help, and to help each other (Pannti et. al, 2012). Since then, publics have increased involvement in disaster mitigation, communicating and contributing independently in and outside of impact zones.

Social networks have only been observed in tsunami warning since 2011, but they have many supporting qualities (Lindsay, 2011). Warnings circulate via publics faster and more often than emergency channels, and social networks are public, horizontal, and networked by design (Lindsay, 2011). Communication flows out, not down, so alerts can reach users simultaneously across time zones or locations, expanding communication speed, volume, and reach enormously. Cross-compatibility, mobility, and popularity have made them redundant and robust. They respond to changing conditions, provide alternate channels for saturated or damaged infrastructure, and connect reliant users to information (Sutton et. al, 2014). These features grant social media important life-saving opportunities.

During Haiti 2010, the US Air Force (UAF) controlled the country's airspace and were not authorizing Medicines Sans Frontiers (MSF) planes carrying supplies and response personnel to land. The UAF had other priorities and MSF lacked a channel to reach them. MSF issued a press release on Twitter that was picked up by NBC journalist Ann Curry (Stanchak, 2010). Her tweet, "@usairforce find a way to let Doctors without Borders [MSF] planes land in Haiti: http://bit.ly/8hYZOKTHE most effective at this", was retweeted enough that Curry made contact and coordinated with the Pentagon to get the planes' clearance (Doctors Without Borders, 2010). Her achievement fiercely demonstrates social networks' ability to expedite communication across social and institutional boundaries, as well as the importance mass participation has in message visibly, import, and authenticity.

Social media are technically and socially interoperable. They make publics, experts, and opinion leaders symbiotically accessible. For example, local updates provide hazard information that aids first response (Palen, 2008; Latonero & Shklovski, 2011). Similarly, first responder tweets are amplified by traditional media and lay users, especially if related to situational awareness, media updates, or fundraising (Bruns et. al, 2012). By putting production into lay hands, information spreads without intermediaries, provides publics alternate sources, and derives pluralistic media reliance, including and exceeding mass media (Jung & Moro, 2014). In doing so, social networks pull traditional media, mitigation experts, and personal networks into the same warning sphere (Sutton et. al, 2014). Social networks are also not subject to the same participatory limits as media spectacle because publics can create them, too. It is, for example, by public retweeting that warnings gain traction (Sutton et. al, 2014; Chatfield & Brajawidgda, 2012). By amplifying public visibility and agency, social networks expand the range of voices that socially construct disasters.

As such, perhaps it is time to redefine disasters as *communicated events.* As social phenomenon constructed through communication, disasters and early warning result from complex tangling of media systems, disaster management, interpersonal communication in networks, and individual characteristics. In this system, agenda setting spurs public involvement by shaping disaster visibility, relevance, severity, and import. Concurrently, interpersonal communication consolidates, validates, and integrates disasters to have collective social significance. In the social media era, none of these components are independent. Social networks combine mass media's speed, reach, and volume with the influence and informality of interpersonal communication, expanding who qualifies as an expert as well who can access and provide feedback to experts directly instead of via broadcasting. Since these events are mediated they remain subject to agenda setting and warning perception conditions, but their production is distinctly participatory where spectacles are witnessed or consumptive. Social media are vehicles for communicated events, expanding mitigation agency and changing the face of disasters as we know it.

## 2.2. Social Media Dependency in a World Risk Society

Ontologically, world risk society (WRS) (Beck, 1992, 2006) is a sociohistorical lens for disasters as communicated events. World risk society is a way of organization that causes and responds to modern disasters (Beck, 1992). Modern disasters result from post-industrial development in a globalized world. Nuclear meltdown or warfare, epidemics, diaspora, famines, or natural disasters with resounding social determinants like Haiti 2010 all fit this bill. They are apexes in manufactured risk spirals that, on rupture, cause new risks to ripple out to uncertain ends. Until they coalesce into tangible hazards, risks are invisible, ubiquitous, and unforeseeable potentials of local origin and global consequence, or vice versa, that can silently span generations. Risks are manufactured from development practices. They afflict people unevenly, with the poor, vulnerable, and marginalized bearing the brunt, but risks that manifest into disasters expropriate the environment to eventually hurt everyone (Beck, 1992). For example, production of fossil fuels runs the risk of oil spills, which cause freshwater and soil contamination, air and marine pollution, biodiversity loss, habitat destruction, or ecosystem instability, all of which accelerate global climate change (Timoney & Lee, 2009). This, in turn, raises disaster likeliness by increasing climate hazards and degrading ecosystems (O'Brien et. al, 2006). Thus, we live in a world risk society as a result of shared potential for self-extinction.

Beneath expropriation's vast umbrella, reflexivity, cosmopolitanism, and manufactured uncertainty institutionalize risk aversion and sensitize publics to disasters (Adam et. al, 2000; Beck, 2006; Lupton, 2013). *Reflexivity* is a cognitive state in which people recognize how they, others, and social systems effect disasters resulting from awareness of their social constituents. *Cosmopolitanism* is global interest in disasters and unification by risk affliction rising from their ramifications. *Manufactured uncertainty* is collective anxiety due to production outpacing its direction or purpose, so embedding risk aversion throughout a society. Together, they create a risk culture that infiltrates post-industrial societies through their techno-development surpluses. This is why social and political action are increasingly framed in terms of risk. Insurance industries, for one, hinge on the idea of controllable risk. There are many other cases besides (Beck, 1992; Haggerty, 2003; Lupton, 2013). Risk determines what is safe, so whoever controls risk discourse controls that decision. Yet, hazards result from negotiations about risk that are far from objective. Context makes the difference between, say, a car stopped at an intersection as an object and an accident in waiting (Fox, 1999). Like warning perception, hazard manifestation is a social process of risk appraisal that is culturally contingent. So are the discourses that have risen to grapple with them, like "accident", "insurance", and "risk assessment" (Beck, 1992). That risk is so politicized highlights its ideological and cultural pervasiveness.

Consequently, mediatization is vital to public debates about risk. Beck (2009) stipulates that there would be no risk without visualization, symbolic forms, or mass media; we would simply have no way to construe it. In this way, disaster relevance in public life has become a vehicle by which risk information is disseminated and opinion is formed. News coverage on Fukushima Daiichi is a case in point. Reflexivity shows in its emphasis on failed disaster preparedness, cosmopolitanism in world economic impacts like derailed silicon production and manufactured uncertainty in bulk health risk omissions, suggesting an attempt by organizers to quell public fears and uphold a business as usual attitude in Japan and abroad (Basu, 2015; BBC News, 2011; Brozak & Bassman, 2011; Pannti et. al, 2012). Thus, world risk society drives an agenda for mediating risk exposure and awareness.

By the same token, risk is a trickster by trade. Unpredictability and volatility invite systemic upheaval (Beck, 2006). As primary risk producers, industrialized nations cannot reduce global crises without infringing on domestic interests (Beck, 1992; Castells 2008). For example, reducing fossil fuels has global benefits but shrinks national economies that rely on oil. Interaction between citizens, civil society, and the state balances stability with social change (Castells, 2008). That balance fails when a state is unable to mitigate global risk, propelling a global civil society with technological means to exist independently from political institutions and mass media (Castells, 2008). US and citizen Geiger readings for Fukushima Daiichi were much higher than official reports. When shared on social media, they spurred protests that forced Japanese officials to recalculate and begin evacuations (Abe, 2011; Osnos, 2011). Castells (2008) calls this shift a rising networked state marked by diversifying relationships between governments and citizens that confront problems evolving from contradictions between national institutions and the transnational networks they are mired in. This conflict is also the reason why Beck (2006) adheres transnational, grassroots coalitions must mitigate disasters; it is only through bypassing communication hierarchies that sociopolitical niches can be leveraged to enact real mitigative change.

Ergo, world risk society creates a sociocultural foundation where disasters can and must thrive as communicated events. It is a cultural well of disaster sensitivity that requires risk mediatization to shape public witnessing, experiencing, and participating in disasters. Reflexivity injects risk into lay awareness and aversion into social systems and institutions. Manufactured uncertainty converts risk into social capital that mediates collective opinion and response. Cosmopolitanism extends risk to incite transnational interest in disasters. Each component bolsters public agency in a networked world. Consequently, when considering disaster mitigation from a world risk society lens, social media’s role is obvious. They enable publics to self-organize and collaborate with disaster response, and because they can work independently the onus on participation world risk society creates provides culturally valid reasons to do so. By bringing myriad stakeholders into one public space, social media support the coalitions needed to mitigate modern disasters.

However, world risk society cannot explain why social media effect public behavior. Here, media systems dependency theory (MSD) is more insightful. MSD states people who rely on ubiquitous media systems are easily influenced by them when social upheaval occurs (Ball-Rokeach & DeFleur, 1976; Ball-Rokeach & DeFleur, 1985). Major disruptions create ambiguity, a stressful cognitive state that elevates information seeking as a way to reduce it. Seeking grants media greater influence as ambiguity renders other sources insufficient.

Multiple regression analysis supports MSD empirically (Loges, 1994). It has also been observed in disasters, including on social media (Vasterman et. al, 2005; Jung & Moro, 2014). Thus, MSD can help contextualize social media behavior in times of uncertainty.

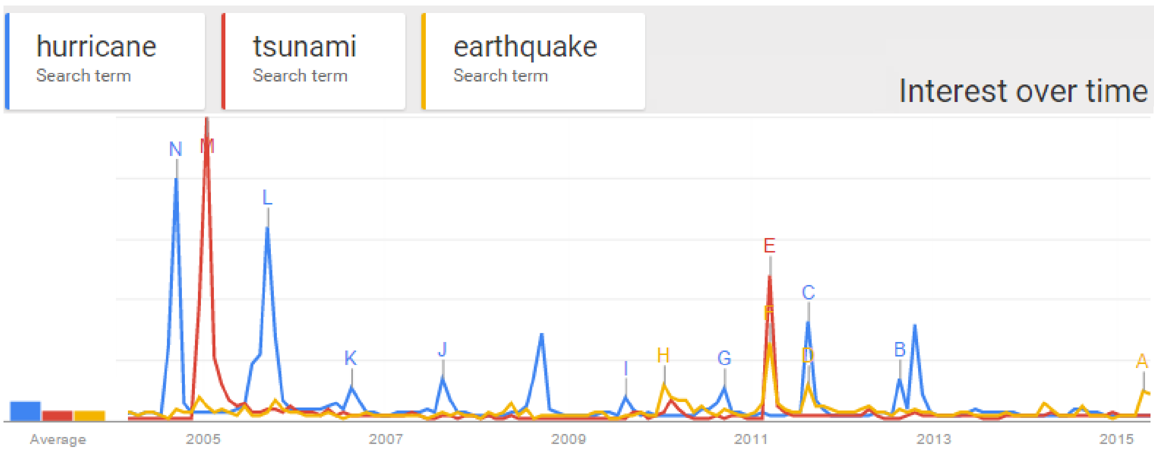



**Figure 2.1 Google Search Trends using disaster keywords**

Functionally, MSD provides an explanation for social media hotspots that appear during disasters. Figure 2.1 is a Google Trends graph of disaster keyword searches from 2005 to 2015. Hurricanes, tsunamis, and earthquakes show similar spikes marked by periods of relative silence. The red “M” corresponds to the 2004 Boxing Day Tsunami, the blue “L” to 2006’s Hurricane Katrina, and the red “E” to 2011’s Tōhoku Tsunami. Social media act similarly (Faustino et. al, 2012; Murthy, 2012; Starbird et. al, 2010). In 2011, Japan’s earthquake was Twitter’s 6th largest topic (Ryo, 2011). At that time, tweets containing “Japan”, “earthquake”, or “tsunami” skyrocketed from less than 500,000 to over 15 million, excluding unrelated posts like marketing promotions (Pingdom, 2011). The spikes reflect increased information seeking in response to disaster, and so visualize MSD in action.

In other words, the activity MSD incites represents temporary converging spaces created as a side effect of information seeking. Twitter satisfied diverse informational needs during Tōhoku 2011. Users mainly checked on others and learned about events (Jung & Moro, 2014). Twitter’s real-time update culture created a window into disaster response that was unfiltered, faster, and covered a wider needs range in one place. In doing so, it drove traffic to the site. Moreover, because social media are participatory, MSD encourages information seekers to produce content, empowering publics to self-influence. *Operation* *ueshima* was a food shortage campaign designed to remind citizens not to panic-purchase and to leave food supplies for areas in need (Okabe, 2011). Twitter users would harshly criticize a Japanese user who mentioned going to a restaurant during the crisis. Afterwards, public opinion of Twitter shifted away from entertainment to a public utility (Jung & Moro, 2014). MSD changed how the site was adopted, used, and perceived. In this way, activity sparked by disasters raises the possibility MSD elevates public influence and shapes responses to risk in social media by blending content seeking with production.

World risk society and MSD are not independent. They feed into and reinforce each other. The former necessitates social media in disaster mitigation to surpass communication hierarchies and bring stakeholders together into a single channel. It orients disasters as communicated events generated by participation and mediatization in a cosmopolitan society. The latter posits communicated events occur as a result of information seeking during disasters, creating networks that influence and are shaped by public activity. Together, they create the theoretical conditions for communication to mitigate disasters in social networks. Although links between WRS, MSD, and social media behavior during disasters are understudied, the literature anecdotally suggest they boost public influence on disaster response and outcomes, and so provide a basis for warnings to operate. For instance, social media users may warn last miles faster by surpassing rigid transmission hierarchies, as occurred during BC's Haida Gwaii earthquake (Anderson, 2015). If so, warning hinges on using networks for interpersonal communication across social strata.

That said, media effects of risk and disaster have been heavily theorized in neoliberal and historical institutions, but how discourse strategies actually operate is under-examined (Hannigan, 2012; Lupton, 2013). Neither world risk society nor MSD were conceived with social media in mind, so this point goes double for disaster warning in social networks. Yet, as this chapter asserts, a highly intersubjective and communicative foundation means warning has always been *networked*; social media simply take the ritual communication underlying warning perception and accelerate and expand it online via user generated content and sharing. Doing so in the temporary, highly reactive and time sensitive social spaces disasters create online applies the same influence that has always shaped warning responses to a wider range of actors and audiences. Both WRS and MSD predict publics will leap to social media during disasters, and the research supports this claim, especially when response follows a traditional and often slower public release model (Sutton et al., 2014). Knowing how social networks are structured to warn in advance is critical to working with them in times of need. To this end, this study adds a foundation to test against real events and to build knowledge on how MSD and WRS shape disaster, risk, and warning mediatization in increasingly convergent public, collaborative, and transnational spaces.

## 2.3. Networked Influence

World risk society and MSD establish a theoretical context for disasters as communicated events that influence warnings and response behavior through social networks. They do not provide a mechanism for influence. Informal opinion leaders are ordinary people who can amplify or attenuate risk in networks using interpersonal communication (Kasperson & Kasperson, 1996). Risk amplification is a key reason why interpersonal communication elicits protective action (Dash & Gladwin, 2007). Since social networks bring users across publics, organizations, and institutions together, they contain opinion leaders from both traditional and non-traditional domains. For instance, first responders use Twitter to connect to locals and develop relationships that hasten emergency response (Latonero & Shklovski, 2011). At the same time, lay people increasingly model appropriate disaster responses, including mourning, supporting, and helping because social media make them more visible (Pannti et. al, 2012). Thus, social networks ebb the usual distance between experts and publics, making communication with them more personal and accessible, while also elevating non-traditional experts like local citizens by providing them greater visibility and audience access. As such, opinion leaders may be a mechanism for influence based on relationship familiarity, interest, and trust. The complexity of these behaviors means a number of moving parts factor into defining influence as it is observed in Twitter.

Influence theory has a long lineage rooted in Katz and Lazarsfeld's (1957) two-step-flow hypothesis. Opinion leaders, it states, are elites who drive trends on the public's behalf. These persuasive, respected, informed, and well-connected gatekeepers alter attitudes and behaviors by driving issue relevancy. Rogers' (2010) diffusion of innovations theory expands this idea beyond mass media. His opinion leaders are lay people who spread ideas through informal networks. They have higher status and innovativeness, lower risk aversion, and greater source access relative to peers, but are members of the systems they influence. They locally sponsor ideas, link people to new concepts, and are behavior models in multiple areas. Trusted status comes from their informality, accessibility, knowledgeability, genuineness, and lack of outside agendas, rather than elite standing (Rogers, 2010). Newer post-structuralist research has shifted focus off individuals and applied Rogers' ideas to relationships and societal readiness to adopt ideas (Watts & Dodds, 2007; Domingos & Richardson, 2001). This approach credits warning spread to network structure, or who is connected to whom and why. It adheres to the Kasperson's (1996) social risk amplification risk model because it marks opinion leaders by relational positions to individuals, institutions, and media or other systems. In this light, networks dynamically influence and are influenced by risk. Anyone can warn under the right network circumstances, from members of the largest industries to the smallest families.

Twitter activity supports the post-structuralist approach. During disasters, face-to-face interactions like talk are conduits for influence (Rjad et. al, 1999). Twitter facilitates similar forms of socializing online, so its users exert influence similarly (Murthy, 2012). Traditional experts like media and civil officials predominate, but any user who is consistent, pertinent, or has a large enough following can trigger others to warn, even lay citizens (Sutton et. al, 2014). Dissemination is a factor of network activity and interconnectivity (Cha et. al, 2010). So, structure and participation take precedence over any one user. Conceptually, a Twitter network is a group of users who follow or mention the same user (ego-centric) or who tweet the same hashtag or keyword (topic-centric). By extension, network opinion leaders can foster credibility and shape consensus (Cha et. al, 2010). Since any user under the right conditions can be an opinion leader, detection is not easy. Exact methods or users vary by network composition (think Lady Gaga versus a high school friend), but opinion leaders share some characteristics. For instance, they are retweeted and mentioned more than regular users (Cha et. al, 2014). They can increase influence by building dedicated and interactive followings (Cha et. al, 2010). Broadcasting outside an area of expertise reduces their influence (Cha et. al, 2010; Sutton et. al, 2014). These behavioral similarities mean social network analysis can detect influentials in spite of their many differences.

However, social media change rapidly, exhibit influence differently, and require platform-centric methods (Goggins & Petakovic, 2014). Longitudinal, cross-platform, and offline studies are also scarce (Goggins & Petakovic, 2014). Influence in Twitter has been studied as global (all-inclusive), local (group-specific), direct (retweets) or affiliative (follows) according to different models (AlFalahi et. al, 2013; Cha et. al, 2010; Dubois & Gaffney, 2014; Goggins & Petakovic, 2014). The type of influence measured produces different opinion leaders (Cha et. al, 2010; Bakshy et. al, 2011). Careful metric selection is required. Global influence prompts the huge cascades that famously shape opinion trends (AlFalahi et. al, 2013). The more and larger the cascades, the more compelling they seem (Bakshy et. al, 2011). Metrics that identify global OLs tend to find users who propagate general interest content like public figures, news agents, or celebrities (Cha et. al, 2010). Usually, follower, re-tweet, and mention counts are the most effective and commonly used metrics, but replies, favourites, and PageRank, a measure of how often a user is returned in search results, are sometimes used as well (Cha et. al, 2010; Goggins & Petakovic, 2014; Kwak et. al, 2010; Sutton et. al, 2014). Yet, a million followers does not make an opinion leader - it only indicates popularity. Single attributes can make users appear more effective than they really are, a bias called the million follower fallacy (Anger & Kittl, 2011; Cha et. al, 2010). Furthermore, giant cascades are rare. A better approach is to identify OLs who exercise less influence across more metrics with more consistency (Bakshy et. al, 2011).

One new method is to shrink networks to only include opinion leaders in interest areas. Networks can be reduced by removing popular users post-sample or by restricting network users or hashtags by limited inclusion criteria pre-sample (Dubois & Gaffney, 2014; Stephansen & Couldry, 2014). Global metrics can then make local opinion leaders more visible, and identify those who belong to target audience networks. Ratios like followees-to-followers or positions within or between groups, like centrality measures, can offset influence inflation even further (Anger & Kittl, 2011; Dubois & Gaffney, 2014; Goggins & Petakovic, 2014). Although understudied, some research has used network reduction in disaster settings successfully (Sutton et. al, 2008; Vieweg et. al, 2010). The opinion leaders this approach detects benefit tsunami warning study because they disseminate public interest content within a specific geographic range. For this reason, this study follows and expands the reduction precedent to pre-event warning networks.

To date, warning networks have been studied using topic-centered approaches defined post-event (Sutton et. al, 2014). This approach identifies qualities opinion leaders share relative to the behavior they cause, but fails to pinpoint which users will influence warning in at-risk areas in advance. More so, influence is causational where homophily, or the tendency for similar users to act in similar ways, is concurrent. Demonstrating influence requires longitudinal data that is hard to come by given that disasters are so often sudden and unpredictable. To this end, the literature is missing a method for detecting influential users in pre-event networks that can then be applied longitudinally. As such, influence in here is not measured by how far OLs disseminate warnings, but rather by their structural potential to do so. The method used to find these users would need to be inclusive of a number of metrics in order to account for different types of influence in a network relative to tsunami risk. A combination of global ratio metrics limited to the CSN's geographic range would meet this requirement, ensuring the widest diversity of OLs is considered.

## 2.4. Warning in 140 Characters or Less

Cumulatively, this chapter has explained and analyzed disasters as communicated events predicated by interactions between world risk society and media systems dependency that influence warning behavior through opinion leadership in social networks. To gauge the practical merits of this sociocultural and methodological framework it is necessary to look at how it applies to recent Twitter applications in disaster mitigation, and to early warning specifically, as well as to how these fit into British Columbia's tsunami warning climate.

As MSD predicts, people go to Twitter when other sources are unavailable or insufficient (Sutton et. al, 2008). Hence, disaster communication differs from regular use. Users share authoritative content more and opinions less (Hughes & Palen, 2009; Starbird et. al, 2010). Repeat information, URLs, and headline, fundraising, hazard, and official tweets dominate (Bruns et. al, 2012; Starbird & Palen, 2010; Vieweg et. al, 2010). Tweet vocabulary has lower variance, indicating consistent goals and topics (Mendoza et. al, 2010). Locals coordinate and draw attention to their environment while non-locals capture events (Starbird & Palen, 2010). Locals also provide situational awareness and geographic or cultural cues, but are oft obscured by popular users and general content like public advisory messages (Starbird et. al, 2012; Sutton et. al, 2014). This happens because retweets reign, and non-locals are usually retweeted most (Starbird & Palen, 2010; Starbird et. al, 2012). However, retweets also increase tweet visibility and credibility. They are critical for disaster communication because they expose content, rouse awareness, repeat salient points, connote recommendation, amplify information, and improve signal-to-noise ratios (Starbird & Palen, 2010; Starbird et. al, 2012; Sutton et. al, 2014). Thus, disasters are evidenced as communicated events by creating social spaces distinct from daily Twitter use, or even to other viral events like elections (Hughes & Palen, 2009).

Additionally, hashtag and content management practices are main conduits for organizing disaster information. For example: #fargoflood linked a town in 2008's Red River floods, #eqnzcontact found relatives after 2011's Christchurch earthquake, and #rescuemehaiti funnelled aid requests after Haiti's 2010 earthquake (Potts et. al, 2011; Starbird & Palen, 2010; Starbird & Palen, 2011). Hashtags are so critical BC (2015a) earmarked #BCStorm, #BCQuake, #tsunami, and #NTWC for tsunami warning. However, hashtags are imperfect curators. They are picked by the first online, often not emergency personnel (Potts et. al, 2011). Competing hashtags, as well as format, word order, and spelling errors can misdirect or cause information loss (Potts et. al, 2011). Users may be unaware, think hashtags are unneeded, or omit them on accident (Potts et. al, 2011). Generic tags are seen and circulated more, and so work better for early warnings. Often, they are paired with locations for clarity, like "Haida Gwaii #earthquake". However, they are prone to misappropriation and false information (Acar & Muraki, 2011; Potts et. al, 2011). Yet, too much specificity limits content visibility. For example, locals and officials were unaware of activist tags used during a toxic spill in North Carolina (Sutton, 2010). Users offset some issues by frequently confirming facts and denouncing false information (Bruns et. al, 2012; Hughes & Palen, 2009; Sutton, 2010; Mendoza et. al, 2010; Spiro et. al, 2012). Still, hashtag etiquette and practices need further refinement. The ways users self-organize and manage disaster content are also indicative of disasters as communicated events.

The most compelling evidence, however, is that Twitter networks themselves support disaster communication. A tweet has as many pieces of metadata as it does characters, including, a user's location, time zone, followers and followees (Krikorian, 2010). Multiplied by the 500 million tweets posted daily, it is easy to see why Twitter brands itself as an information firehose. Its huge, amorphous datasets and massive user networks correlate to behavior at unprecedented scales and complexity, and may even assist event detection (Earle, et. al, 2010; Sakaki et. al, 2010). In 2012, over 6,000 users in Indonesia retweeted a tsunami warning thirteen times a second after an earthquake (Chatfield & Brajawidgda, 2012). Most were urban, lived outside the impact zone, and did not follow one another, a pattern replicated in the Tōhoku tsunami (Chatfield & Brajawidgda, 2012; Acar & Muraki, 2011). Lower interconnectivity may mean better reach (Chatfield & Brajawidgda, 2012; Miyabe et. al, 2012). For instance, non-locals may act as “information hubs” that relay warnings (Hughes & Palen, 2009). A hub’s warning could be passed along to other, potentially local, networks or via tertiary means like a phone call. Networks are the core reason Twitter’s content cornucopia and userbase facilitate early warning. They are so timely some users have seen warnings before feeling the ground shake (Murthy, 2012).

That said, warning tweets struggle relative to other disaster tweets. Most are incomplete and posted reactively (Sutton et. al, 2014). Publics follow warnings better when they are specific, contain instructions on what to do, provide time before impact, are communicated over multiple channels, and are frequently reported and repeated (Mileti & O’Brian, 1992). However, length limitations mean tweets reference only one or two of these at a time. For instance, evacuation tweets often omit where evacuees should go, for how long, or what to expect during and afterwards, stating only that an evacuation must take place (Sutton et. al, 2014). As a result, warnings can be too general to act on. Improvement is possible when strategies tap into local needs, understand how users process risk, and provide the information needed to respond. For example, warning tweets in an area’s native language gather volume faster, are timelier, and are better received (Doan et. al, 2012). Thus, transmission can be improved by tapping into ritual, local contexts, but are still subject to innate platform limitations. As such, Twitter is a better a compliment than supplement to early warning systems (Sutton et. al, 2014). To use it successfully, official information must be timely and first response must jump in the moment an event occurs, prompt retweets, connect with locals on scene, and appropriate or encourage hashtags and other tweet syntax etiquette as needed. Emergency managers who build networks in advance using consistent, locally targeted tweeting syntax often achieve better outcomes (Starbird & Stamberger, 2010). As such, strategies that differentiate local and non-local needs and leverage networks to make warnings visible for target groups are urgently needed.

Twitter is a life-saving communication tool because it enables rapid, up-to-date exchange that satisfies informational needs (Sutton et. al, 2014). However, it remains to be seen how it applies to tsunami warning in BC specifically. Distant tsunamis 1,000km away or more can wreak havoc on BC's outer coast. For these, early warning grants minutes to hours of lee time for identifying, alerting, and evacuating at-risk areas. Local tsunamis within 1,000km pose greater risk. BC's end-to-end coastline is 965km$^2$, but when its many fjords and islands are considered it is closer to 25,725km$^2$. Its spiny terrain puts coastal settlements in low-lying areas where run-up risk is high, increasing damage potential and decreasing lee time for local events (Anderson, 2015). Waves that reflect off islands, underwater landmasses, or outside coasts are even harder to predict and increase risk in both cases (NTWC personal communication, Dec. 3, 2014). As such, BC's current warning system responds well to distant tsunamis, but struggles with local events. Sensory information from the NTWC in Palmer, Alaska flows to EMBC's provincial system. After assessing the threat, EMBC activates a public response subsystem coordinated by international, federal, provincial and local authorities, volunteer agencies, and other stakeholders (Anderson, 2015). From there, mass media spread the alert while local technologies facilitate response. These can include door-to-door, radio, pagers, broadcast sirens, telephony, television, the Internet, or social media, and vary by region and municipality (Anderson, 2006; Anderson, 2010; Anderson & Gow, 2004).

As such, hardware, infrastructure, geography, and design issues limit Twitter's efficacy in BC. Last mile populations are plentiful, and include remote rural communities, transient, floating, or seasonal groups like labour camps, outdoor ecotourists, or anyone who cannot recognize physical tsunami warning signs like ground shaking or rapid tide recession (Anderson, 2010; Anderson, 2015). Any lapse in warning lee time can be catastrophic, and for these groups especially. However, Twitter penetration in BC is substandard; only 21% of social media users are on Twitter weekly (Insights West, 2013). Twitter is also not designed for emergency use. Mass activity has brought the platform down before (Olenick, 2014). Twitter's capacity continues to improve, but without a demand cap it is unknown how many resources would make it fail-safe. Platform rules can raise other issues. Twitter once banned the Calgary police in the middle of a flood for exceeding its allowable number of posts (Bogart, 2013). Overload is only half the battle. In a disaster, communication lines are often damaged where they are needed most. Tweets chew through bandwidth and are hard for older devices to parse. Moreover, at almost 950,000km$^2$ BC is massive, and Internet, data and cellular coverage are incomplete (Anderson, 2015). If ICTs withstand damage or overuse, most last mile groups have one or no service option (Anderson &

Gow, 2004). Infrastructure damage is unlikely for distant tsunamis, but is a risk for local events. In either case, saturated lines make response efforts harder to execute.

Where Twitter is available, social determinants may still limit warnings. BC is multicultural. Its 4.6 million population contains large indigenous and immigrant communities as well as intersecting age, gender, and socioeconomic stratifications across a vast rural-to-urban schism. Children and the elderly, disabled, poor, or non-English speakers may be unwilling or unable to receive warnings (Bobkowski, & Smith, 2013; Canadian Internet Registration Authority, 2014; Haight et. al, 2014; Garcia-Gavilanes et. al, 2014). Rural and captive populations like hospital patients are in similar boats. Even those who do use Twitter may decline to participate. Disaster responders may find linguistic and cultural demands for crafted messages too great to meet. Users may feel exploited when third-parties use their content and restrict their sharing, truncating their ability to warn (Hughes et. al, 2008; Madden & Smith, 2010). Information inundation is also a problem (Sutton et. al, 2008). Ensuring audiences see the most up-to-date content is a huge task, and authority loss resulting from public contributions is raising concerns that official warnings may be ignored (Vieweg et. al, 2008). These barriers to coordination can block last mile access entirely.

These obstacles limit Twitter's viability for early warning in BC to the limited subset of people who are comfortable using the technology in the absence of industry standards or support. Nevertheless, Twitter continues to expand in the wake of global disasters. Account reactivations and long term site adoption increase in times of crisis (Hughes & Palen, 2009). Experience using Twitter for disaster communication also increases public appreciation of the medium (Jung & Moro, 2014). Twitter's utility will expand as mobility, need, and platform familiarity grow in BC and preventative research like this study can help support that interest. Where connectivity exists, mobility and convenience mean a greater likelihood of Twitter use compared to less common mediums like satellite phones. A last-mile group like a kayak tour may not see a tsunami's signs or receive an official alert, but if anyone in the party uses Twitter a warning may be seen. Tsunami response requires rapid, ad-hoc stakeholder mobilization and coordination, and robust, integrated, Province-wide policies and technologies (Anderson, 2015). Twitter has begun adapting to meet these needs. If it saves even one person, that's a win for the entire community.

Overall, ensuring warnings reach audiences and that users can optimize tweet creation, curation, regulation, and uptake, are two core challenges in disaster management today (Acar & Muraki, 2011; Potts et. al, 2011; Sutton et. al, 2014). In the narrow window before a disaster's landfall early warning seeks to evoke an immediate evasive response, like moving to higher ground or sheltering in place. However, technology and social response capability gaps mean warnings must be understood in context of information access and compliance differences across vulnerable social groups (Taubenbock et. al, 2009). Social media have permanently altered the speed, reach, and source of risk information. They have changed how we experience, navigate, and understand disasters as communicated events. By doing so, they have extended influence, agency, and therein the ability to warn beyond technical experts or elites to include new professions and even members of the public. Twitter's horizontal communication platform and increased user agency have thus created new opportunities for socially relevant and culturally embedded warning using the informal channels of influence available in online user networks. These in turn can be applied in service to select publics in British Columbia who leverage the technology.

## 2.5. Research Questions

The need for social networks is so great the United Nations (2013) has mandated disaster management adopt them if the field is to continue serving the people it aims to protect. In the social media era, disasters have graduated from media spectacle to communicated events, better positioning WRS to act beyond geographic barriers to mitigate disasters. Content reaches large audiences, has potential to incite collective action, and is conducive to sharing across stakeholder groups. Users bypass communication hierarchies and interoperability barriers to speed public disaster information access, a principle motivation for why people seek social media. These attributes suggest MSD drives social media use during disasters, and fosters the participatory networks we see emerging as traditional communication methods and sources become insufficient. These networks foster the coalitions WRS stipulates are essential for modern disaster mitigation. Limitations to the medium, both in terms of early warning and adoption in BC, mean Twitter is not a perfect solution. Rather, the site is an emergent technology with potential to solve problems WRS has established by enabling disparate actors and organizations to mitigate risk together.

Studying how a Twitter pre-event network is positioned to disseminate tsunami early warnings is a major step towards improving interoperability in disaster management. It augments reactive research by providing a comparative baseline, and enriches knowledge of how stakeholders are prepared to communicate during catastrophe. It also offers an opportunity to discuss WRS and MSD as precursory frameworks for communication to mitigate disasters, opening new avenues to studying these theories in online social networks. To investigate these concerns, this thesis compares stakeholders and opinion leaders in a Twitter tsunami early warning network for the Pacific Northwest Coast. It assesses warning capacity in BC specifically by answering these core research questions:

1. What does a PNC pre-event tsunami early warning network look like?
2. Who are the stakeholders and where are they located relative to tsunami risk?
3. Which stakeholders are influential opinion leaders (OLs)?
4. How do OLs use and what do they think about Twitter as a warning medium?
5. Do the opinions of rural/urban, strongly/weakly connected, and high/low use OLs differ by country or stakeholder group in ways that impact early warning capacity in BC?
6. Do OL reports on Twitter benefits and limitations match best practices in the literature?
7. How can a PNC Twitter network best assist tsunami early warning in BC?

This knowledge will give disaster mitigation stakeholders a better idea of where to focus efforts to improve warning efficacy by granting insight into the potential consequences and flow of warning dissemination through networks. There is a distinct dearth of accurate and geographically focused prediction of protective actions in response to warnings (Dash & Gladwin, 2008). As such, this thesis establishes a precedent for detecting, engaging, and studying networks for disaster early warning. Disaster management can be enriched by the critical study of Twitter networks, just as the theoretical understanding of Twitter can be enriched by applied mitigation practices. This study chips away at the monumental task of determining what a pre-event tsunami early warning network in Twitter looks and how users perceive the platform's utility in relation to the study's theoretical framework. Doing so provides an opportunity to understand how BC's practices compare to those of out-of-Province stakeholders and to the best practices recommended in the current literature.

# Chapter 3.

# Methods: Navigating Networks

Charting a pre-event tsunami warning Twitter network along the Pacific Northwest Coast (PNC) requires stringent inclusion criteria and empirically grounded operational definitions that keep an eye to practical limitations in data collection and interpretation. To limit these, a dataset should suit the research questions asked (Boyd & Crawford, 2012). Big data studies have analyzed Twitter during disasters to track warning timing and dispersion, show how communities dispel misinformation, or explain communication patterns (Chatfield & Brajawidagda, 2012; Mendoza et. al, 2010; Middleton et. al, 2014; Starbird & Palen, 2010 Sutton et. al, 2014). In contrast, small data studies provide an in-depth look into how people actually see, think about, and experience social media during disasters (Acar, & Muraki, 2011; Hjorth & Kim, 2011; Latonero & Shklovski, 2011). Small data studies are an important resource because they enrich and deepen our understanding of big data phenomenon (Stephansen & Couldry, 2014). The research design laid out in this chapter uses a small data model like Acar and Muraki's (2011) that combines social network analysis and user surveys to gain rich insight into a specific community. As per Canada's Tri-Council Policy Statement (2010), precautions to protect users and their data were taken (Appendix 2). All survey participants signed informed consent forms and were supplied results and feedback. Public data is free to access as per Fair Dealing set out by Canada's Copyright Act (2013). However, individuals may not intend for their information to be publicized. To ensure maximum protection, no names or accounts are published and all locations are collapsed into larger municipalities or regions. Simon Fraser University's Ethics Review Board classified this study as minimal risk.

## 3.1. Population and Sample

The study population was tsunami warning invested Twitter users on the PNC. The NTWC issues bulletins for all tsunamigenic events that could impact the PNC, as well as the Atlantic coast of US and Canada, the Gulf of Mexico, and Puerto Rico, and @NWS_NTWC exists to push those bulletins, and nothing else, to Twitter (NOAA, 2014). Bulletins are watches, advisories, warnings, or updates (NOAA, 2014). All use the syntax, “BULLETIN TYPE: URL for alert areas. Event magnitude, location, time, date, other information: #NTWC” (Figure 3.1). NTWC manually selects bulletins and issues them via an automated service (NOAA, personal communication). Their exclusive strategy reduces post time, minimizes irrelevant content, and builds authenticity, which improves protective actions (Sutton et. al, 2012). It also gives users little other reason to follow @NWS_NTWC. An ego-centric follower network built around it could thus access the target population. Its base unit of analysis would be follower ties, which mark warning communication lines.

On February 11, 2014, a network of 9,998 NTWC Twitter followers and 70,054 edges was sampled with NodeXL, of which 60,058 ties were between followers only. At that time, @NWS_NTWC had 11,657 followers so the sample contained 86% of its network. Imported metadata included all users’ total followees, followers, and tweets, profile descriptions, URLs, and device and self-reported location. From April 1 to June 30, the sample was coded and reduced to public accounts in English located in the PNC. This filter was applied because private or non-English accounts could not be analyzed. As well, private accounts did not apply to public information networks, and only PNC users were eligible.

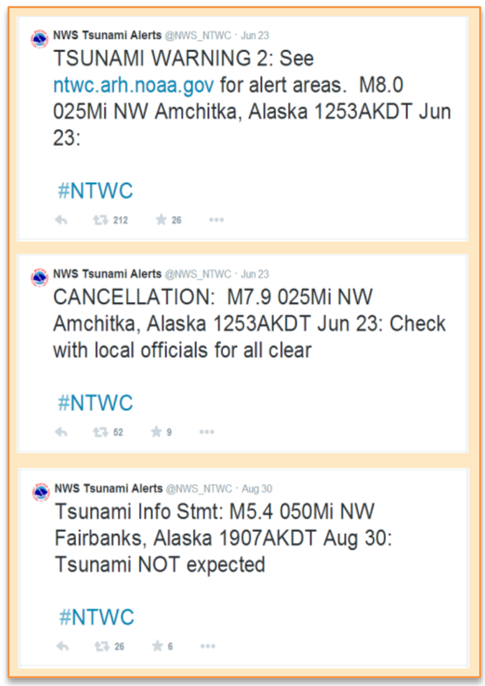



**Figure 3.1 NTWC Bulletins**

Moreover, self-reporting indicates place better than device location (Hemsley & Eckert, 2014). Place is an area with strong sociohistorical attachments; it’s not just where users are, its home (Hemsley & Eckert, 2014). In all, 60% of users self-reported while 2.1% used device location, which matches other studies (Hemsley & Eckert, 2014). So, self-reporting is not only more relevant, it also enables larger location based networks. As such, it was a considerably more suitable inclusion criterion than Cartesian coordinates. However, self-reported data had to be standardized. If a user listed multiple locations the first was picked unless a succeeding location was in the PNC. Euphemisms were re-coded, but only if they were easy to interpret. Locations were coded by continent, country, province/state, and municipality to the nearest possible value, and their spellings cleaned. Many locations were blank, too general, such as “worldwide”, phrases, like “living my life”, or applied to two or more places. In these cases, profile descriptions, URLs, and if needed most recent fifty tweets were also reviewed in an effort to deduce a location. Accounts that could not be coded were removed from the sample.

The result was 2,285 accounts in the PNC. Of these, 1,595 specified a location down to the municipal level. Municipalities were assigned coordinates and mapped with ArcGIS (Figure 3.2). Those with 150 persons or less per square kilometre, or under 5,000 residents total, were designated “rural”. All others were marked “urban”. Finally, @NWS_NTWC and all ties to it were removed so that only follower connections were visible. This reduced sample was dubbed the “Cascadia Subnetwork” (CSN) and accounted for 23% of @NWS_NTWC’s total.


**Figure 3.2 CSN Geography**

## 3.2. Content Analysis

Each user was assigned into one of nine mutually exclusive stakeholder groups (SGs): academia, citizen, first responder, government, hobbyist, media, private or public sector, or professional (Table 3.1). SGs qualify roles users’ fill in relation to tsunami warning. They describe shared properties, enable role mapping, and allow variable comparisons. There is no dictionary for classifying accounts into disaster management SGs. To accommodate this absence, SGs were carefully operationalized. Definitions were adapted from the Justice Institute of British Columbia’s (2010) key words and stakeholder definitions and Hannigan’s (2012) work on international disaster management. Lastly, consultation with research community members helped quality assure the coding process.

Definitions were created during the SG assignment process via a content analysis (CA) post-coded as per Bailey and Hackett’s (1997) recommendation for changeable term sets.

This method followed Herring's (2004) computer mediated model for discourse analysis, which labels texts according to word frequencies. The units of analysis were profile bios and URLs. Up to fifty recent tweets were included if these were insufficient. SGs were confirmed by perusing the "About" or similar sections of URL sites, or by searching online for equivalent information when these were insufficient. Many referenced social media, blogs, or websites about interests, hobbies, volunteering, or work, such as Facebook, about.me, or LinkedIn. These checks clarified which SGs content in question fell into. As key terms were extracted notes were made about each account's relation to disaster management, like "Military" or "Meteorology". These themes were grouped into nine SGs. This process reduced redundancy, increased user counts, enhanced mutual exclusivity, and improved validity. While some accounts fell neatly into one SG, most fell into two or more and a selection protocol was needed. A five-step system was designed to assign users the most suitable SGs.

**Table 3.1 Stakeholder Group Inclusion Criteria**

| Group | Examples |
|---|---|
| Academia | Public or private facilities serving kindergarten to grade 12, college, university, or adult or vocational education, university labs and research facilities, as well as under- and post-graduate students, faculty, and support or administrative staff. |
| Citizen | Any person who identified no relation to DM or could not be assigned a stakeholder group. |
| First Responder | Fire, police, paramedic and first aid, or search and rescue departments, groups, and members. |
| Government | Civil servants, government run organizations or programs, politicians and staff, army, navy, or air force members, and regional organizations or members. |
| Hobbyist | Amateur HAM radio operators, radio scanners, emergency blogs or sites, news aggregators, forecasters, outdoor enthusiasts, survivalists, and storm chasers. Fandom, such as for disaster television, and mock or satire accounts were also included. |
| Media | News, radio, television, film, and their production, journalists, photographers, videographers, meteorologists, citizen journalists with emergency related blogs, podcasts, streaming applications, or websites; and, Twitter based news accounts. |
| Private Sector | For-profit enterprises or members, including: hotels and resorts, tourism, restaurants, real estate, public relations or marketing, construction or building inspection, commercial fisheries, small businesses, and solo entrepreneurs with company names. |
| Professional | Skilled or employed persons without a stakeholder group, including artists, writers, photographers, lawyers, realtors, software developers, retail workers, office staff, and emergency or weather workers without a specific organization. |
| Public Sector | Crown corporations, utilities or public works, immigration, transportation, or infrastructure services, hospitals, trade and union boards, churches and religious services, emergency or environmental management, volunteer group, or public-private partnership organizations, free or open-source software developers, or basically any private, for-profit, non-profit, or government organization serving public interests and their members. |
| N/A | Not enough information |

First, if an account was directed by an organization, the organization SG took precedence. Second, if there was no organizer or additional SGs remained possible, an audience tier system prioritized accounts by tsunami warning responsibility. Tier one was assigned to government, media, public sector, and first responders, as they warn publics (Anderson & Gow, 2004). Tier two pertained to private sector, hobbyists, and academia, as they warn narrower populations, like clients. Tier three was for citizens and professionals, as they are traditionally removed from disaster warning. Third, if two or more SGs had the same tier, assignments were prioritized by employment, volunteer, and interest time investment. The words "work", "job", "full-time", "part-time" "paid", "salaried", or "intern" or a URL to an employer's website indicated employment, while "volunteer", "hobby", "amateur" or a URL about these terms indicated a volunteer, and "enjoy", "like", "love", "passion", or "interest", or a URL to personal sites like a travel blog marked interest use only.

Fourth, if no affiliation was found content weighting was used. SG content in bios, URLs, and, if needed, most recent fifty tweets were weighted "1" regardless of term frequency for a maximum of 3. The weightiest SG was picked. Tweets are cumbersome to code and were only used when no URL or description was present or a tie occurred. Fifth, if all steps failed, the first SG found was used. For example, if an account had no description or URL, but mentioned search and rescue (First Responder) in its 4th tweet and journalism (Media) in its 9th tweet, the user would be a "First Responder" because that SG was mentioned more recently. Alternatively, if multiple same-tier SGs like "civil servant" (Government) and "Red Cross" (Public Sector) were listed without a URL or identifying content in tweets, "Government" would apply because "civil servant" was written first. If an account had no SG assigned by the end of the five-step system, it was marked as "Not Available" and removed from the CSN. This final filtering reduced the CSN to 1,932 accounts and 9,687 follower ties, representing users in the PNC with assigned stakeholder groups and their relationships. This final filter reduced the sample to 19% of @NWS_NTWC's total network and marked the final version of the CSN as presented in this project.

## 3.3. Influence Analysis

The ratios for calculating influence were the followers-following ratio ($r_f$), interaction ratio ($r_i$), retweet-to-mentions ratio ($r_{RT}$), and page rank (*P*). High $r_f$ scores mean more people are interested in receiving a user's updates without that user having to reciprocate (Anger & Kittl, 2011). Consequently, $r_f$ is a measure of *authenticity*, the tendency to be considered reliable. The higher $r_i$, is, the more users are retweeted or mentioned relative to their total followers (Anger & Kittl, 2011). This ratio measures *reach,* or the ability to engage others beyond immediate follower networks. The higher the $r_{RT}$, the more retweets and mentions users inspire relative to their total tweets (Anger & Kittl, 2011). This metric can be seen as *persuasiveness,* or the ability to prompt action with little effort. Finally, the more times an account is linked to without it linking out the higher its $P$ (Berkhin, 2005). Thus, $P$ measures *popularity,* or how liked and in-demand users happen to be.

It was easy to calculate $r_f$ and $P$ using CSN data but $r_i$ and $r_{RT}$ required longitudinal data. To save time, the free services Retweet Rank and TweetReach were used. Retweet Rank compares a user's recent retweets to their current followers, followees, and lists. It then compares these ratios to those of other users and assigns a percentile rank. The higher the rank, the more a user is retweeted. Thus, Retweet Rank is a proxy for $r_i$. TweetReach calculates the total users who see another user's recent tweets. That number is divided by the user's total tweets to determine how far their tweets travel. This ratio is a proxy for $r_{RT}$, as the more users reached connotes retweet or mention activity. Relying on company-developed metrics is risky in that their algorithms are never made public. Further testing with RetweetRank and TweetReach to measure $r_i$ and $r_{RT}$ is needed. That said, concealed metrics are industry standard for any analytics service, even Twitter itself. The issue is a limitation, but is for the most part unavoidable when studying online social networks.

Operationally, the CSN's opinion leaders are *authentic*, have *reach,* can *persuade*, and are *popular* as per $r_f$, $r_i$, $r_{RT}$, and $P$. Each metric is important, but opinion leaders will be more influential in some over others. In order to measure influence across the various social spheres these metrics represent, and to ensure that different types of influentials are included in the opinion leader survey, it was necessary to look at influence across all four metrics. Doing so ensured the most diverse range of OLs in the CSN were included. As such, each metric was ranked from highest (1) to lowest (1,932) and the ranks were added to produce an overall influence score for each user. These results were re-ranked, and the top 25% were selected as the CSN's opinion leaders. This subset contained 491 users and 6,109 edges, making up 0.05% of @NWS_NTWC's total sample.

Granted, a 25% cut-off point is somewhat arbitrary, having been selected by research criteria rather than a firm statistical divider. However, if opinion leaders are derived from network position, then influence is a gradient and not a dichotomy and applying a cut-off point makes sense (Watts & Dodds, 2007). Cross-checking the CSN calculation against self-reported influence in the user survey would help test the validity of this approach. To assist this check, opinion leaders were divided into five intervals: Tier 1 ran from 0% to 5%, Tier 2 from 6% to 10%, Tier 3 from 11% to 15%, Tier 4 from 16% to 20%, and Tier 5 from 21% to 25%. If the higher tiers also reported being more influential, network calculated influence would be demonstrated and its validity confirmed.

## 3.4. Social Network Analysis

Twitter networks are not only groups of users who follow each other, but a communication system built by stakeholders vying to meet personal and collective needs. This study uses social network analysis to describe how CSN stakeholders and OLs connect within and between groups. This data can be compared to survey responses to see if opinions about Twitter reflect the CSN's structure and warning capacity. A number of OL, SG, and network level metrics are needed to conduct this analysis. As is consistent with SNA literature, during analysis users are referred to as *nodes* and follower relationships as *edges.* Nodes that only follow the ego, @NWS_NTWC, are called *isolates.*

*User Metrics*

**In-degree:** Incoming connections from others in a network (Scott, 2013). It shows a user's total followers, or warning recipients, in the CSN. Users with 100 or more were "Strong" (n = 17), 11 to 99 were "Moderate" (n = 243), 1 to 10 were "Weak" (n = 815), and 0 were "Isolates" (n = 859). Strong and moderate ties were regrouped as "Strong" and weak ties and isolates as "Weak" categories in cross-tabulated OL survey analysis. Strong tie OLs are well-connected. Weak tie OLs may have connections for influence outside the CSN.

**Out-degree:** Outgoing connections to others in the network (Scott, 2013). It indicates a user's total followees, or redundant warning sources, in the CSN. This study does not look at out-degree directly, but uses in other calculations, such as reciprocated edge ratios.

*Stakeholder Group Metrics*

***Reciprocated Node-Pair Ratio*: ** Total adjacent nodes who mutually follow a user divided by the CSN's adjacent nodes (Weingart, 2014). The ratio ranges from 0 to 1 and is used as a group level clustering co-efficient. It tells us roughly how 'small-world' the group is. Users in small world networks do not necessarily know one another, but can communicate with few steps. Small world tendencies indicate a group's internal communication ability.

***Reciprocated Edge-Pair Ratio:*** Total dyads, or paired users who follow one another (Weingart, 2014). The ratio ranges from 0 to 1. High numbers indicate mutual communication. In groups, the ratio signals isomorphic homophily or the tendency for similar users to follow one another because they occupy similar roles (McPherson et. al, 2001). Thus, it is a measure of how similar group members are to each other.

**Connected Components:** Subgroups with connections between two or more users who have no other incoming or outgoing ties (Wasserman, 1994). They can have few nodes and many edges, or many nodes and few edges. A SG with many or strongly connected components with many users and edges indicates empirical groupings and conceptual definitions are sound. Thus, this metric provides external validity by showing how insular a group is, or how well its members are connected while excluding other groups.

**Closeness Centrality:** Total nodes outside a group who are connected to it. The ratio ranges from 0 to 1, and is produced by dividing the nodes not connected to a group by the connected nodes minus the group's total members (Everett & Borgatti, 2005). The shorter the paths between users, the more direct information transfer is (Scott, 2013). Thus, closeness centrality indicates which groups can reach other groups (Everett & Borgatti, 2003; Ni et. al, 2011). High closeness centrality shows external communication capacity.

**Betweeness Centrality:** The number of times a user bridges the shortest path between two other nodes (Scott, 2013). It identifies how well a SG transfers information between two weak or non-connected groups (Everett & Borgatti, 2003; Ni et. al, 2011). High betweenness indicates paths between SGs are much longer and so take more time and effort to use (Scott, 2013). This metric indicates which groups are critical for ensuring information spread between poorly or non-connected groups.

*Network Metrics*

**Direction:** Graphs can be *undirected*, meaning edges have no additional meaning, or *directed*, meaning edges indicate which way information flows from a sender node to a receiver (Scott, 2013). Follower relationships in Twitter are one-directional, meaning information flows from followee to followers, so a directed network was used in this study.

**Reciprocity:** Proportion of node pairs with mutual ties (Scott, 2013). Mutual ties facilitate information transfer between users. If they occur more or less often than chance predicts, reciprocity is a defining characteristic of a network. If the CSN has less reciprocity than its stakeholder groups, those groups are better connected than the network, and vise versa. High reciprocity indicates an ability to transfer information but low reciprocity indicates that neither the CSN nor its stakeholder groups are effective at sharing information.

**Density:** The ratio between actual edges divided by total possible edges that measures how connected the CSN is overall (Scott, 2013). Density ranges from 0 to 1, where 0 means no users follow others and 1 means all users follow each other (Sohn, 2009). A high density network is a stable, symmetrical, near-complete, and highly social. A low density network is the opposite. Egocentric networks like @NWS_NTWC's are often low density because users tend to only have the ego node in common.

**Modularity:** The density of connections between groups that detects communities of users who are more alike than chance predicts (Newman, 2006; Scott, 2013). It is used to detect big groups in large networks. It ranges from 0 to 1, and larger values indicate denser ties within and few between groups. So, it is an indicator of exclusivity, or the tendency for groups to be close to others. Usually, modularity is not used in directed graphs because it does not distinguish where edges begin and end. However, this study is interested in path presence rather than flow, so modularity can be applied as if the graph were undirected.

**Geodesic Distance:** The average shortest path between all nodes that indicates a network's diameter (Wasserman, 1994). Typical average geodesic distance is 2.0 (Scott, 2013). In the CSN, a high average distance would indicate a large diameter. If so, the potential for information transfer between users is weaker. If the shortest path between any two users is smaller than average, information transfer is higher than the norm.

## 3.5. Survey Design

CSN OLs (n = 491) were invited to participate in an online survey about Twitter use and coastal hazard and risk perceptions. Of these, 167 replied and 121 completed the survey. Almost half (57) were weak ties. Overall response rate was 25% for invitations sent, and 72% for replies. The distinction is important as it is not possible to confirm users received the invite. If users were offline or had heavily saturated feeds, it may have not been seen. The semi-structured survey had 39 closed and open-ended questions and an informed consent form (Appendix A). It was administered between August 1st and August 31st, 2014. OLs were recruited on Twitter and linked to a website for details, contact information, and survey access. Twitter and email were used to provide feedback, answer questions, and follow-up on inquiries. Due to the study's exploratory origin, no templates were available. Instead, the survey was reviewed by departmental faculty and peers, and pilot tested (n = 13) to minimize possible biases and reliability and validity concerns.

Questions were divided into topic areas. Questions 1 through 15 collected validation or demographic data. The purpose was to verify OLs were of age (19+) and CSN followers, as well as to collect location and account purposes. They also checked the reasons why OLs followed @NWS_NTWC, how often they paid attention to its content, and whether OLs worked or volunteered in specific stakeholder disaster management. Some SG names were changed in the survey. "Other" replaced academics, as so few were found during the network analysis, and professionals, because of their loose inclusion criteria. "Technologist", a scientist or expert, was added to assess this role across categories. "Media" was split into "Traditional' and "Social" to differentiate the two. "None" replaced the "Citizen" group. These amendments simplified the selection process, as participants were able to pick multiple roles to correspond with potentially pluralistic relationships to disaster mitigation. Location and stakeholder group questions were used to validate coded Twitter data accuracy against actual user reporting. Any part of the analysis that compared survey and network findings recoded roles back into their original categories.

Questions 16 to 21 investigated the OL's opinions about using Twitter for tsunami or other coastal hazard community response. Questions 22 to 27 asked them to report on their average time spent on weekly Twitter use, as well as how much of that time was disaster related in an average day. As tsunamis are rare, the questions pertained to disasters generally to include a wider range of responses. Questions 28 to 31 asked participants to rate how important they felt Twitter was to disaster communication, their level of general and coastal hazard awareness, and their perceived ability to influence others. Questions 32 and 33 asked participants to report additional access to tsunami warning information sources. Questions 34 to 38 asked participants about hashtag and information control preferences for disaster and tsunami information. Lastly, question 39 asked for approval to publish responses prior to submitting the survey.

## 3.6. Variable Summary

This study uses social network analysis to examine how tsunami warning stakeholders are grouped, what kinds of bonds and communities they form internally and externally, and how these vary by country (Canada or USA), community type (rural or urban), or in-degree (strong or weak). It compares follower relationships and patterns against user attributes in order to identify communities and structures based on roles in disaster early warning as a conceptual framework for interpreting the CSN. Identifying communities using network metrics helps us to better understand how the CSN's warning capacity is socially structured and whether it aligns with disaster mitigation practices. This descriptive approach to network analysis informs readers on how the CSN's various participants and in particular its opinion leaders are positioned to assist in tsunami early warning in BC both as groups and as a collective.

The opinion leader survey treats SGs as a dependent variable that can be compared to country, community type, in-degree, and opinions about Twitter's role in disaster warning as independent variables. This approach clarifies how these factors vary between and within different SGs. The survey attempts to answer how OL's think about and use Twitter to qualify their positions in the CSN and to inform understanding of how well these align with the network's warning capacity and best practices outlined in the current literature. Combining the survey with the social network analysis helps answer the key question of how Twitter can best aid tsunami mitigation in BC, and, more importantly, how to improve on current practices in order to optimize its benefits and minimize its shortcomings.

# Chapter 4.

# Network Findings: Tweeting Tsunami

Results from the social network analysis reveal the CSN as a poorly connected network with stakeholder groups that differ from one another structurally, across countries, and in access to last-mile remote, rural communities. In particular, stakeholder group capacities for internal sharing, broadcasting, connecting disparate groups, or acquiring information are shown to assist communication, but only at small scales. This chapter delves into those findings and assesses whether or not the CSN is prepared to warn BC communities.

NTWC's network is global. Of the 9,998 followers sampled 5,958 (60%) provided locations in 104 sovereign and dependent countries or territories (Figure 4.1). Most were located in the US or Canada (Table 4.1). In particular, PNC areas, BC, AK, WA, OR, and CA, made up 56% of all Canadian and US users. Followers were split almost fifty-fifty for each country, with 1,285 (56%) in BC and 1,000 (44%) in the US. When the network was filtered down to just the Cascadia Subnetwork (CSN), or the 1,932 users on the PNC with a stakeholder group assigned, this divide persisted. 1,098 (57%) users reported a BC home base while 834 (43%) reported one in the US (Figure 4.2). Yet, BC contained 84% of Canadian followers whereas AK, WA, OR, and CA made up just 43% of US followers. Together, these data point to three main conclusions that open the door to further analysis.

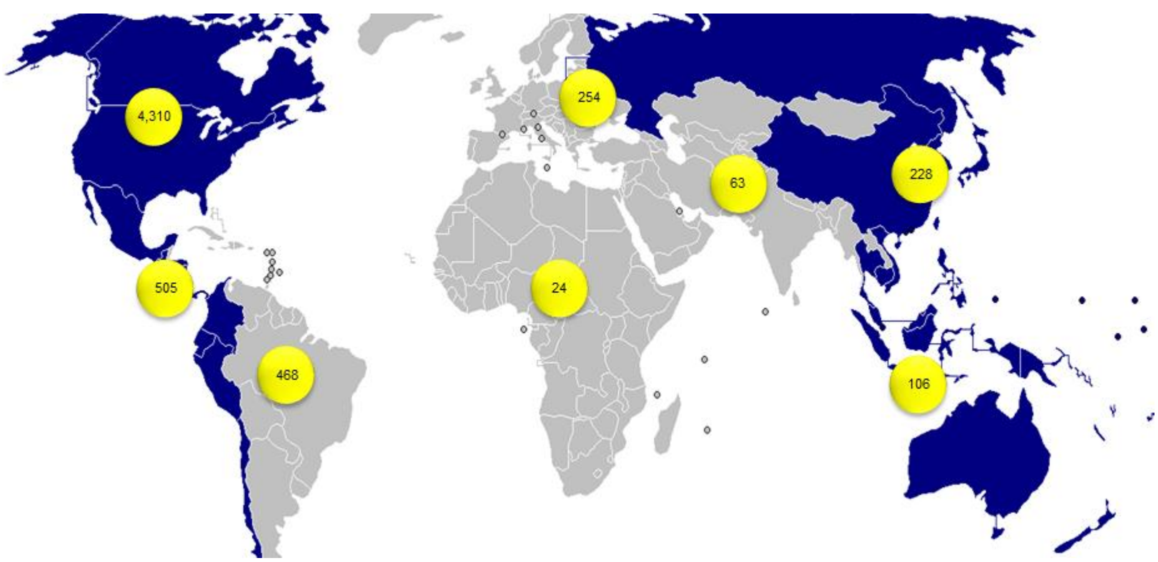



**Figure 4.1 @NWS_NTWC Followers by Geographic Region**

**Table 4.2 Countries by Coastal Access**

| Coastal Access | *Followers* | *%Count* | *Countries* | *%Count* |
|---|---|---|---|---|
| ***Pacific Rim*** | 5,102 | 85.6% | 32 | 30.7% |
| ***Non-Pacific Rim*** | 856 | 14.0% | 72 | 69.2% |
| *Other Oceans* | 717 | 12.3% | 31 | 29.8% |
| *Seaside/Bayside* | 125 | 2.1% | 32 | 30.7% |
| *Landlocked* | 14 | 0.2% | 09 | 8.6% |
| *Total* | *5,958* | *100%* | *104* | *100%* |

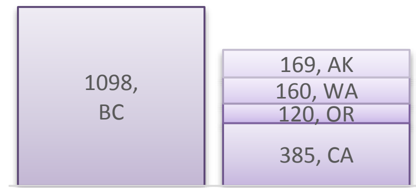



**Figure 4.2 CSN Locations**

**Table 4.1 PNC Highlighted NTWC Countries by Geographic Region**

*N. America,* ***4,310***

USA, 2492
Canada, 1607
Mexico, 211

*Europe,* ***254***

United Kingdom, 67
Spain, 51
Germany, 24
Italy, 18
Netherlands, 15
France, 13
Ireland, 13
Greece, 10
Sweden, 7
Belgium, 5
Switzerland, 5
Russia, 5
Norway, 4
Poland, 3
Austria, 2
Belarus, 1
Bosnia, 1
Bulgaria, 1
Denmark, 1
Estonia, 1
Greenland, 1
Iceland, 1
Malta, 1
Portugal, 1
Serbia, 1
Ukraine, 1
Moldova, 1

*C. America/Caribbean,* ***505***

Puerto Rico, 352
Panama, 49
Dominican Republic, 41
Costa Rica, 17
Guatemala, 11
El Salvador, 10
Honduras, 10
Nicaragua, 4
Barbados, 2
Guadeloupe, 1
Guyana, 1
Jamaica, 1
St. Kitts & Nevis, 1
Trinidad & Tobago, 1
Grand Cayman, 1
British Virgin Is., 1
Turks & Caicos Is., 1
Anguilla, 1

*Oceania & Micronesia,* ***106***

Australia, 63
New Zealand, 18
Guam, 13
Fiji, 6
New Caledonia, 2
Tasmania, 1
Tonga, 1
N. Mariana Islands, 1
French Polynesia, 1

*S. America,* ***468***

Chile, 171
Ecuador, 95
Venezuela, 57
Peru, 56
Colombia, 35
Brazil, 25
Argentina, 21
Uruguay, 6
Bolivia, 1
Paraguay, 1

*W & S Asia,* ***63***

India, 16
Sri Lanka, 14
Maldives, 6
UAE, 5
Pakistan, 4
Iraq, 2
Kuwait, 2
Oman, 2
Saudi Arabia, 2
Syria, 2
Turkey, 2
Palestine, 1
Afghanistan, 1
Bangladesh, 1
Israel, 1
Lebanon, 1
Qatar, 1

*E & SE Asia,* ***228***

Japan, 127
Indonesia, 23
Philippines, 22
Malaysia, 20
Thailand, 16
China & HK,13
Brunei, 2
Cambodia, 2
Taiwan, 2
South Korea, 1

*Africa,* ***24***

South Africa, 12
Egypt, 3
Mauritius, 2
Algeria, 1
Ghana, 1
Kenya, 1
Malawi, 1
Morocco, 1
Nigeria, 1
Sudan, 1

First, as suspected PNC followers have a vested interest in tsunami warning for their area. Most countries in NTWC's network are coastal or islands. A third were seaside or bayside, and only nine were landlocked. A third bordered the Pacific Rim and held 86% of the sample, most of whom were in the PNC (Table 4.2). It is unlikely, then, that the PNC's high number of followers is coincidental. Many of Twitter's most active users are in non-

Pacific Rim countries like Brazil or India (Sysomos, 2014). As such, the PNC's particularly high distributions are likely to be more interest than access based.

Second, since PNC followers are vested in tsunami warning information, NTWC's role as an ego for a PNC warning network is justified. As such, opinion leaders who act as warning conduits for local areas are likely present. Third, BC appears to rely on NTWC more than the US or the rest of Canada. Most Canadian followers are in BC, and BC holds a majority over AK, WA, OR, and CA combined even though almost twice as many followers are in the US. In a way, the discrepancy makes sense. NTWC connects to BC one-to-one via EMBC whereas US ties include local, state, and national bodies. For example, the US National Weather Service has state and local accounts that warn (e.g. @NWSSeattle). As such, US users may have more access to local tsunami warning sources, and more may follow NTWC outside the PNC because of this formalized system. Conversely, EMBC's sole official output is @emergencyinfobc. Volunteers and civil servants provide informal support, but no localized alert system is in place for Twitter at this time. Cumulatively, the data demonstrate NTWC's followers constitute a tsunami warning network positioned to communicate with users in the PNC. Now, it falls to investigating user locations relative to risk, how those users are involved in disaster mitigation, and the ways they utilize Twitter to answer whether and how well the CSN can warn areas in BC when the need arises.

## 4.1. Warnings on the West Coast

**Table 4.3 Network Metrics**

| Metric | *NTWC* | *CSN* | *OLs* |
|---|---|---|---|
| *Users* | 9,998 | 1,932 | 491 |
| *Nodes* | 6,742 | 1,611 | 451 |
| *Isolates* | 3,256 | 310 | 41 |
| *Edges* | 60,058 | 9,687 | 6,109 |
| *Density* | .001 | .004 | .030 |
| *Modularity* | .145 | .115 | .099 |
| *R. Edge* | .29 | .35 | .48 |
| *Avg. Geo* | 3.7 | 2.8 | 2.8 |

The CSN and its OLs are structurally distinct from NTWC (Table 4.3). Density is low in all three cases. There were only 6,109 edges between OLs out of a possible 242,063, and they had the highest density in the study. As NTWC is filtered to the CSN, then to OLs, density increases slightly from 0.1% to 3.0%. Low density suggests all networks mainly have NTWC in common, which matches studies finding tsunami warning networks are ego-centric and incohesive and suggests the CSN will behave similarly in live events (Chatfield & Brajawidgda, 2012; Acar & Muraki, 2011).

Because all three networks have low modularity, none contains large communities. In fact, cross-network clusters actually decrease in the smaller networks. However, modularity cannot detect small groups. In this, reciprocated edge ratios are more useful. Reciprocity is about a third for the NTWC and CSN, but almost half for opinion leaders. Thus, the more influential CSN users are, the more likely small groups can communicate with each other. Network similarity also increases when users have things in common (McPherson et. al, 2001). Mutual interests, locations, vocations, or offline access may make OLs more likely to reciprocate ties. Thus, reciprocity indicates these influentials share structural similarity and commonalities that supersede location, community, stakeholder group, or in-degree.

Isolates also support OL familiarity. They fall from 33% in NTWC, to 12% in the CSN, to just 8% for OLs. The drop shows many CSN users and even more OLs follow at least one other user. Thus, the CSN, and OLs in particular, are more able to share information than is NTWC. All three networks have a geodesic diameter above 2.0, so all are inefficient at network-wide transfer. However, the CSN and OLs are only nominally so. Likely the absence of dense community structures is responsible. Still, OL similarities highlighted by better density, higher reciprocity, lower modularity, and fewer isolates suggest homophily. Homophilous networks are fast at idea adoption and diffusion because members behave similarly (McPherson et. al, 2001). As such, OLs may have greater chances of seeing and sharing tsunami warnings with other influentials, enabling faster response times compared to the CSN. Consequently, OLs are likely to see, share, and act on warnings the fastest of all PNC users, underscoring their importance as warning and response initiators.

Lastly, poor network wide communication does not exclude small group coordination or outside reach. Users may be better connected than the metrics illustrate. They may own multiple accounts, know one another personally, or even work together offline, and indeed high reciprocity between OL dyads suggests such familiarity is the norm. Still, connections outside the CSN are unknown. What is clear is that communication across NTWC's global network, the CSN, and OLs is truncated. However, the increases in density and reciprocity and decreases in geodesic distance imply that smaller networks within the CSN contain sub-communities that can warn. What remains to be seen is whether these groups can reach each other across stakeholder, country, community, and connectivity (in-degree) groups or whether they are for all intents and purposes isolated by their lack of ties.

## 4.2. Stakeholder Diversity

Follower ties connote interest in receiving information and enable access to it via Twitter's newsfeed feature. As such, they are lines of communication from followees to followers, and so represent pathways for tsunami warning. Most of the CSN are citizens (654) or professionals (302). The private sector (255) and media (250) nearly tied for third and fourth place, with government (135) in a distant fifth. Public sector (87), hobbyist (86), first response (82), and academia (81) made up the tail. For the most part, stakeholders were split evenly across Canada and the US. However, Figure 4.3's country tally shows more BC users in all groups. When put to a Chi-square goodness of fit test, countries differ less than they appear (Table 4.4). At $\alpha$ = .05 and *df* = 1, Canada has more citizen ($X^2$=21.291, p<.001) first response ($X^2$=19.512, p<.001), private sector ($X^2$=11.863, p<.001) and professional ($X^2$=10.384, p<.001) users, and if $\alpha$ is raised to .1 the US has more media ($X^2$=3.136, p=.077) users. The other groups show no country level differences.

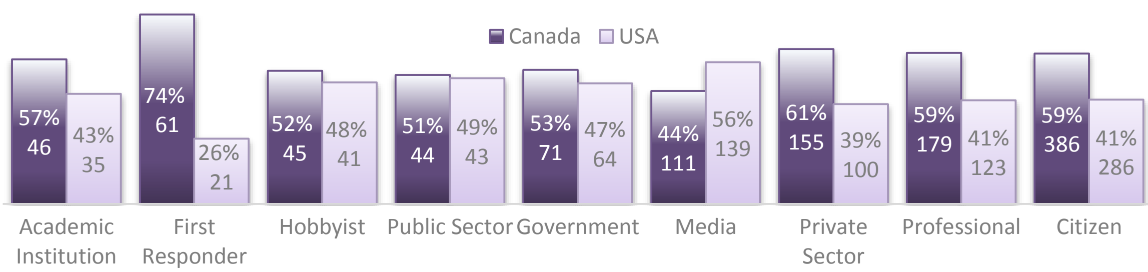



**Figure 4.3 Stakeholder Group Distributions by Country**

Undoubtedly, variations in population density, demographics, access, infrastructure, and social media enculturation influence these differences. Overall, BC holds 57%, California 20%, Alaska 9%, Washington 8%, and Oregon 6% of the CSN (Table 4.4). However, BC's coastline is also 27,200km$^2$ and its population 4.61 million whereas AK (.74), WA (7.1), OR (3.97), and CA (38.8) have about 12,700km$^2$ of coastline and 50.71 million people combined. A larger coastline and smaller populace may mean BC's increased users and stakeholder differences mark larger rural and urban divides or a greater reliance on Twitter and NTWC relative to limited notification source or resource availability. Thus, significant differences for some groups and not others highlights a need to delve into social practices and geophysical conditions surrounding Twitter engagement that may or may not cause discrepancies. These are addressed in Chapter 5's survey analysis findings.

**Table 4.4 Stakeholder Crosstab and Chi-Square by Country with US States**

| *Stakeholder Group* | *AK* | *WA* | *OR* | *CA* | ***ALL (USA)*** | ***BC (CAN)*** | ***Total*** | ***$X^2$ (2 tailed)*** |
|---|---|---|---|---|---|---|---|---|
| ***A. Institution*** | 7 | 10 | 3 | 15 | **35** | **46** | 81 | **$X^2$=1.491** |
| *% Row Total* | 8.64% | 12.35% | 3.70% | 18.52% | **43.21%** | **56.79%** | 100% | ***p*= .222** |
| *% Column Total* | 4.14% | 6.35% | 2.50% | 3.90% | **4.20%** | **4.19%** | 4.19% | |
| ***Citizen*** | 58 | 46 | 36 | 128 | **386** | **684** | 654 | **$X^2$=82.994** |
| *% Row Total* | 8.87% | 7.03% | 5.50% | 19.57% | **40.98%** | **59.02%** | 100% | ***p*< .001*** |
| *% Column Total* | 34.32% | 26.75% | 30.00% | 33.25% | **32.13%** | **35.15%** | 33.85% | |
| ***First Responder*** | 5 | 3 | 1 | 12 | **21** | **61** | 82 | **$X^2$=*19.512*** |
| *% Row Total* | 6.10% | 3.66% | 1.22% | 14.63% | **25.61%** | **74.39%** | 100% | ***p*<.001*** |
| *% Column Total* | 2.96% | 1.88% | 0.83% | 3.12% | **2.52%** | **5.56%** | 4.24% | |
| ***Government*** | 16 | 13 | 8 | 27 | **64** | **71** | 135 | **$X^2$=*0*.363** |
| *% Row Total* | 11.85% | 9.63% | 5.93% | 20.00% | **47.41%** | **52.59%** | 100% | ***p*= .547** |
| *% Column Total* | 9.47% | 8.13% | 6.67% | 7.01% | **7.67%** | **6.47%** | 6.99% | |
| ***Hobbyist*** | 3 | 9 | 10 | 19 | **41** | **45** | 86 | **$X^2$=*0.186*** |
| *% Row Total* | 3.49% | 10.47% | 11.63% | 22.09% | **47.67%** | **52.33%** | 100% | ***p*= .666** |
| *% Column Total* | 1.78% | 5.63% | 8.33% | 4.94% | **4.92%** | **4.10%** | 4.45% | |
| ***Media*** | 24 | 24 | 32 | 59 | **139** | **111** | 250 | **$X^2$=3.136** |
| *% Row Total* | 9.60% | 9.60% | 12.80% | 23.60% | **55.60%** | **44.40%** | 100% | ***p*= .077** |
| *% Column Total* | 14.20% | 15.00% | 26.67% | 15.32% | **16.67%** | **10.11%** | 12.94% | |
| ***Private Sector*** | 28 | 13 | 12 | 47 | **100** | **155** | 255 | **$X^2$=11.863** |
| *% Row Total* | 10.98% | 5.10% | 4.71% | 18.43% | **39.22%** | **60.78%** | 100% | ***p*< .001*** |
| *% Column Total* | 16.57% | 8.13% | 10.00% | 12.21% | **11.99%** | **14.12%** | 13.20% | |
| ***Professional*** | 21 | 33 | 14 | 55 | **123** | **179** | 302 | **$X^2$=10.384** |
| *% Row Total* | 6.95% | 10.93% | 4.64% | 18.21% | **40.73%** | **59.27%** | 100% | ***p*< .001*** |
| *% Column Total* | 12.43% | 20.63% | 11.67% | 14.29% | **14.75%** | **16.30%** | 15.63% | |
| ***Public Sector*** | 7 | 9 | 4 | 23 | **43** | **44** | 87 | **$X^2$=0.011** |
| *% Row Total* | 8.05% | 10.34% | 4.60% | 26.44% | **49.43%** | **50.57%** | 100% | ***p*= .915** |
| *% Column Total* | 4.14% | 5.63% | 3.33% | 16.30% | **5.16%** | **4.01%** | 4.50% | |
| ***Total*** | 169 | 160 | 120 | 385 | **834** | **1,098** | 1,932 | **$X^2$=36.075** |
| *% Row Total* | 8.75% | 8.28% | 6.21% | 19.93% | **43.17%** | **56.83%** | 100% | ***p*<.001*** |
| *%Column Total* | 100% | 100% | 100% | 100% | **100%** | **100%** | 100% | |

Although groups do not differ much cumulatively, they vary widely in geography. BC and US state comparisons show groups ranging from 3% to 6% for academics, 29% to 35% for citizens, 1% to 6% for first response, 6% to 9% for government, 2% to 8% for hobbyists, 10% to 27% for media, 8% to 17% for the private sector, 12% to 21% for professionals, and 3% to 6% for the public sector (Table 4.4). Most citizens and first response are in BC, more media and hobbyists are in OR, most academics and professionals are in WA, most government and private sector are in AK, and most public sector are in CA or WA. This study focuses on country differences because state level samples were too small to study. However, the increased variation relative to narrower geographic focus importantly instills a precedent to delve deeper into local geographic differences in future research, especially as they relate to tsunami warning, emergency management practices, and demographics in BC. At this stage, this descriptive analysis visually demonstrates that the CSN has tangible membership differences. These most certainly impact how groups communicate.

## 4.3. Networked Communication

The introductory image for this thesis is a graph of the CSN. Node colours indicate groups and edge colours denote tie destinations. For example, if an edge from a citizen (purple) to a hobbyist (red) is purple, the hobbyist is the follower. If red, the citizen is the follower. The graph shows the CSN's dominant information sources are traditional elites, media and government. Their few tightly tied nodes nest inside a moderate-tied cloud circled by many outliers and isolates from other groups. Poor organization reflects absent community structure, so manual isolation makes groups easier to study. Group densities ranged from .001 to .003 and .016 to .065, allowing a relative divide (Figure 4.4). 'Low' density groups have high isolates and low reciprocity. Academics follow others but few reciprocate in turn. Hobbyists are similar but have citizen and private sector followings. Reciprocity between professionals, citizens, and the private sector is better, but just. These groups are not well knit despite being the CSN's largest. 'High' density groups have fewer members, denser edges, and greater reciprocity. Government and media are quite well known to each other. Follower overlap between both and the public sector is strong as well. First responders are relatively closed in comparison. They tend not to follow other groups except media, to whom they are quite tied, yet are important information sources for all neighbours.

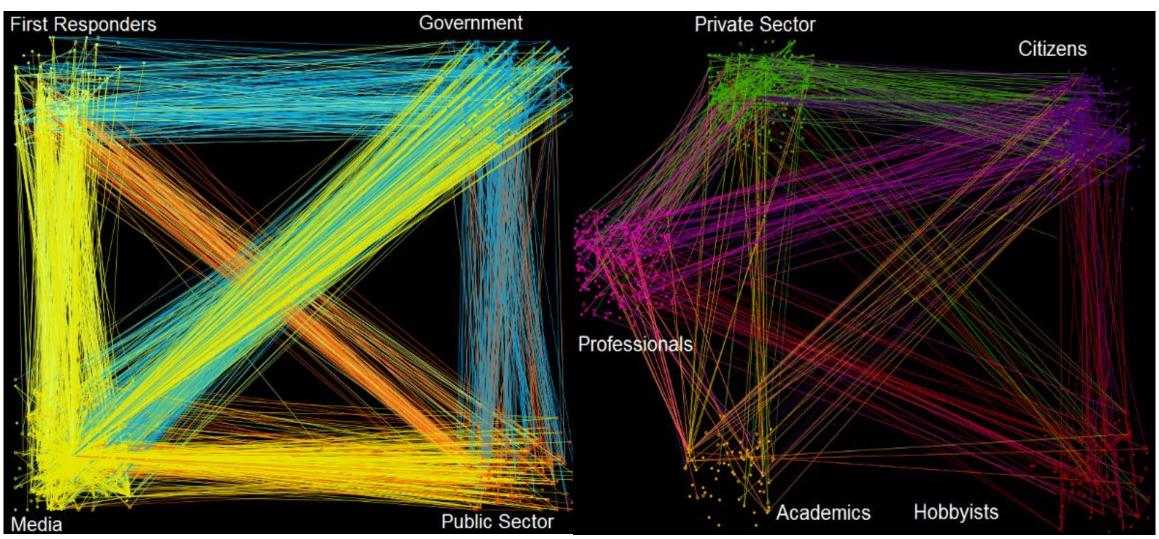



**Figure 4.4 High (Left) and Low (Right) Density Stakeholder Groups**

Network metrics clarify these observations (Table 4.5). Briefly, *N.* represents connected nodes, *E* edges, $N_r$ reciprocated node pair ratios, and $E_r$ reciprocated edge ratios. *CC* stands for connected components, and $M_N$ and $M_E$ are the largest component's total nodes and edges. *BC* is betweeness centrality, *DC* is closeness centrality, and *d* is density. $R_{i/o}$ marks followers-to-followees and $R_{fw/fr}$ outgoing-to-incoming edge ratios. Ratios over .75 are strong and .50 are moderate.

**Table 4.5 CSN Stakeholder Group Descriptive Statistics**

| *Group* | *N.* | *E.* | $N_r$ | $E_r$ | *CC* | $M_N$ | $M_E$ | *BC* | *DC* | *d* | $R_{i/o}$ | $R_{fw/f}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Aca. I* | 52 | 8 | .14 | .25 | 5 | 4 | 3 | 0.81 | .07 | .003 | 1.69 | 0.50 |
| *Citizen* | 391 | 106 | .52 | .67 | 18 | 22 | 40 | 2.36 | .24 | .001 | 0.76 | 0.26 |
| *FR* | 70 | 329 | .44 | .61 | 1 | 61 | 314 | 2.23 | .21 | .065 | 3.83 | 0.96 |
| *Govt* | 110 | 336 | .30 | .46 | 1 | 97 | 326 | 3.53 | .58 | .027 | 7.46 | 2.21 |
| *Hobby* | 72 | 12 | .33 | .50 | 6 | 5 | 7 | 1.11 | .11 | .002 | 1.99 | 0.49 |
| *Media* | 199 | 1,247 | .35 | .52 | 4 | 167 | 1,054 | 3.28 | .85 | .027 | 5.73 | 1.66 |
| *PrivS* | 167 | 153 | .43 | .60 | 7 | 60 | 132 | 3.72 | .18 | .005 | 1.12 | 0.46 |
| *Prof* | 188 | 74 | .67 | .80 | 11 | 4 | 6 | 0.79 | .23 | .001 | 0.79 | 0.37 |
| *PubS* | 68 | 25 | .37 | .54 | 1 | 37 | 74 | 3.05 | .14 | .016 | 4.16 | 1.10 |

**Academics** have a few weak connected components, low node and edge pair ratios, low centrality, low density, and the lowest betweeness of all groups. More users follow outside groups than are followed, and most ties are outgoing. Thus, academics bridge poorly tied groups, but are not tightly tied, popular with others, or fast external communicators.

**Citizens** have moderate node and edge pair ratios and the most albeit weak components. Betweeness is high, centrality is low, and density is the lowest of all. Follower to followee counts are near equal, but most edges are outgoing. Subgroups can communicate well but internal communication is poor overall. Citizens do not bridge or boost communication for other groups. They receive from myriad outside sources, but cross-sharing is limited.

**First responders** have moderate node and high edge pair ratios, one strong component, the highest density of all, high betweeness, and low centrality. They have more followers than followees, but similar outgoing-to-incoming edges. Thus, the group is not a bridge and does not boost external communication, but its' internal communication is very strong.

**Government** has one connected component with many users and ties, but low node and edge pair ratios. Betweeness is the second highest, as is closeness. They have low density and slightly more followers than followees, with more incoming than outgoing ties. Thus, government users are not well knit internally and do not bridge unconnected groups. However, they are good at getting a message to outside groups quickly.

**Hobbyists** have a few small and loosely tied components, low node and moderate edge pair ratios, and low density. Centrality measures are low, fewer users follow the group than are followed, and more edges are outgoing. So, hobbyists do not communicate well internally or externally, but they do broker information between disparate groups well.

**Media** have few weak and one strong component plus low node and moderate edge pair ratios. Betweeness is high and centrality is the highest of all, despite moderate density. They have more followers than followees, and more incoming ties. Thus, media is neither a cohesive group nor a bridge, but nevertheless it has strong internal communication and is the CSN's fastest external channel, likely due to their high reciprocity with other groups.

**Private Sector** has many weak connected components, and moderate node and edge pair ratios despite their low density. They have the highest betweeness and low centrality, more followees than followers, and more outgoing ties. The group is moderately cohesive with many reciprocal dyadic pairs. It is not adept at internal communication, does not act as a bridge, and is not fast at disseminating information to other groups.

**Professionals** have numerous weak connected components, a moderate node pair and the strongest edge pair ratio of all groups. They have low centrality measures and density, more followees than followers, and more outgoing edges. Thus, professionals are a bridge that is both loose-knit and insular. External communication speed is low, whereas internal communication is strong but restricted to the group's many dyads.

**Public Sector** has a moderate component, low node and mid edge pair ratios, moderate density, high betweeness and low centrality. They have more followees than followers, but incoming-to-outgoing edges are near exact. The group neither bridges groups nor expedites external communication, but its many dyads suggest a strong internal capacity for collecting and sharing diverse information.

The data demonstrate different stakeholder strengths in the CSN. Academics, hobbyists, and professionals are *information brokers*. They help disconnected groups access CSN content. Media and government are *information boosters*, with large followings that ensure information spreads quickly. First response and public sector are *information coordinators,* they leverage their dyadic channels to access and share content internally, and externally in small capacities. Lastly, private sector and citizens are *information seekers.* They follow other groups, often in dyadic pairs, allowing individual access to diverse sources. Although they are generally not well connected enough to act on that information collectively, they are positioned to receive input from many sources that they can use individually.

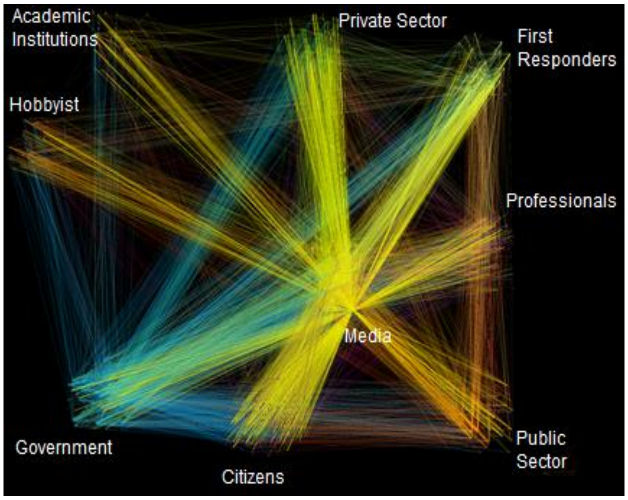



**Figure 4.5 All Density CSN SGs**

Figure 4.5 shows connectivity relates to warning capacity. Academics can pass warnings from media, government, the public sector and professionals to the private sector and citizens. Hobbyists do so from first response, media and government to professionals and the public sector. Professionals can bridge public, private sector and media to hobbyists, academics, and citizens. In particular, professionals are a diverse group whose members are more tied with other groups than each other. Media warnings can be heard well by all groups, whereas governments are best heard by media, first response, citizens, and the private sector. First responders warn each other and mainly receive from media and government. The public sector is similar but receives from media, first response, and hobbyists instead. The private sector obtains information from all groups but only really disseminates to first responders. Citizens who are not isolates follow other groups indiscriminately, namely government and media, and also sporadically disseminate to media and professionals. Some of these findings seem intuitive. For example, university academics often connect disaster management groups through applied and theoretical research. Thus, the bridge role academics fill in the CSN is akin to one they perform offline. Similarly, fewer academics work in emergency management than do government or media, so a reduced presence and warning capacity in the CSN make sense. Together, these data illustrate how networks can validate typically common sense relationships within a bigger picture comprehensive of many participants. In doing so, they act as a platform for examining how groups facilitate or impede early warning in social networks as a communication system.

## 4.4. Proximity to Risk

The CSN's greatest risk for local tsunamis is in the minor form of shoreside or underwater landslides or the major form of earthquakes (Anderson, 2015). These are predicted to occur in the Cascadia Subduction Zone between Southern BC and CA, the San Andreas Fault along CA, the Aleutian Trench under AK, and the Queen Charlotte Fault in Northern BC. Coastal communities exposed to the open Pacific Ocean are BC's most vulnerable. The area's rural communities that lack dedicated warning infrastructure are even more so.

**Table 4.6 Community Types Crosstabulation by Country with Chi-Square**

| *Country* | *N/A* | *Rural* | *Urban* | *Total* |
|---|---|---|---|---|
| ***BC*** | **173** | **166** | **759** | **1098** |
| *%Row* | 15.8% | 15.1% | 69.1% | 100.0% |
| *%Col* | 51.3% | 69.7% | 55.9% | 56.8% |
| ***USA*** | **164** | **72** | **598** | **834** |
| *%Row* | 19.7% | 8.6% | 71.7% | 100.0% |
| *%Col* | 48.7% | 30.3% | 44.1% | 43.2% |
| *Total* | 337 | 238 | 1357 | 1932 |
| *%Row* | 17.4% | 12.3% | 70.2% | 100.0% |
| *%Col* | 100.0% | 100.0% | 100.0% | 100.0% |
| $X^2$ | .24 | 37.126 | 19.102 | 36.075 |
| *p* | .624 | .001* | .001* | .001* |

The CSN was 12% rural, 17% non-reporter, and 70% urban. By country, a Chi-square goodness of fit test ($\alpha = .05$, $df = 1$) found no difference between Canadian and US non-reporters ($X^2 = .24$ $p = .624$), but a significant difference between rural ($X^2 = 37.126$, $p < .001$) and urban ($X^2 = 19.102$, $p < .001$) users (Table 4.6). Thus, both countries have proximal non-reporters but, even though BC has more urban users overall, proportionately there are more in the US. The reason is because BC's rural userbase is significantly larger, comprising a full 70% of the CSN's rural users.

Figure 4.7 maps the 1,595 users who listed a CSN municipality. Most live along exposed coasts or concentrate in urban hubs: The Greater Vancouver and Victoria areas (BC), Seattle (WA), Portland (OR), and San Francisco or Los Angeles (CA). Alaskan users, as the exception, were dispersed. The presence of rural users confirms some BC last mile communities access NTWC content. Nevertheless, rural representation is low. This dearth is concerning considering remote communities face elevated tsunami risk. Where there is infrastructure, cultural reasons are likely preventing Twitter adoption. These will need to be understood in order to get these communities online access to NTWC warning content.

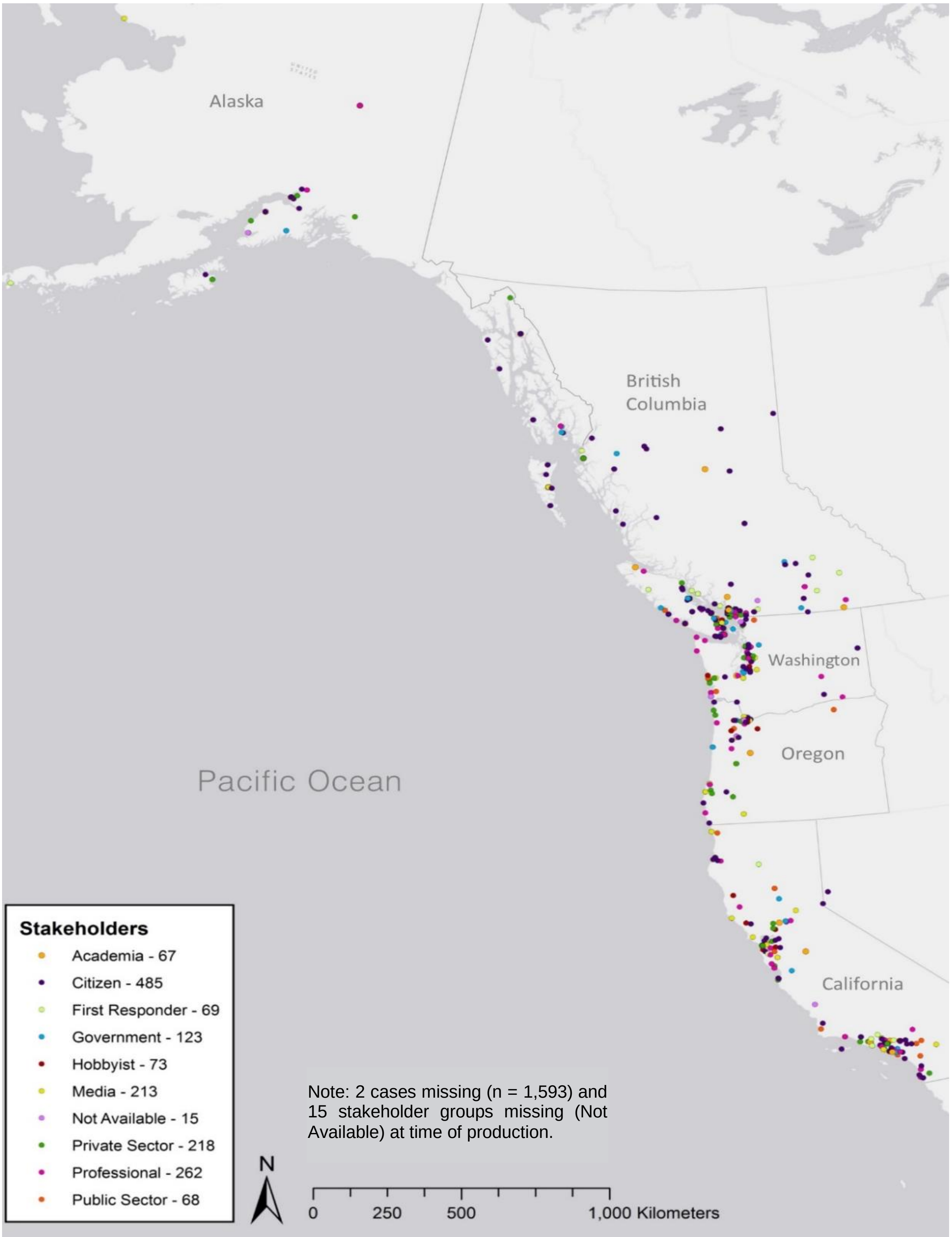



**Figure 4.6 Map of Stakeholder Groups in British Columbia**

BC's (2015c) coasts are split into five tsunami notification zones. Zone A covers North Coast and Haida Gwaii. Zone B covers the Central Coast and Northern Vancouver Island. Zone C covers Vancouver Island's outer West Coast and Zone D its' Southern Coast. Zone E covers the Strait of Georgia. Zones A to C contain the most remote communities with limited infrastructure, transient groups like permanent, semi-permanent, and fishing and logging camps, and recreational groups like kayakers, boaters, or hikers (Anderson, 2015). The region also has seasonally mobile First Nations communities and festivals, like the Helitsuk Nation's Tribal Journeys, where canoeists from as far north as Alaska and as far south as Washington journey to a location in BC or WA each summer (First Nations Technology Council, 2015; Anderson, 2015). Demographic diversity, fluctuating populations, and limited infrastructure mean many people in this part of BC are hard to find and harder to notify. Mobile groups could benefit from fast, robust, wireless alerting technology like Twitter, yet are the least likely to be using it (Anderson, 2015). Notably, most of BC's rural users are in the highest risk Zones A to C (Table 4.7). Representation is particularly scarce in Zone B.

**Table 4.7 BC Rural Communities Listed by Tsunami Notification Zone**

| **Zone A 29** | **Zone B 15** | **Zone C 37** | **Zones D & E 33** |
|---|---|---|---|
| Haida Gwaii | Alert Bay | Ahousaht | Baynes Sound |
| Kincolith | Bella Bella | Bamfield | Campbell River |
| Masset | Bella Coola | Hot Springs Cove | Chemainus |
| Port Clements | Kitimat | Tofino | Cowichan |
| Port Simpson | Klemtu | Ucluelet | Cumberland |
| Prince Rupert | Port Hardy | Zeballos | Galiano Island |
| Sandspit | Port McNeill | | Gibsons |
| Skidegate | | | Gulf Islands |
| | | | Lantzville |
| | | | Mayne Island |
| | | | Protection Island |
| | | | Quadra Island |
| | | | Salt Spring Island |
| | | | Savary Island |
| | | | Thetis Island |
| | | | Metchosin |
| | | | Otter Point |

The CSN had more rural first response and government, urban media and professionals, and non-reporter citizens (Table 4.8). Between countries, BC had more rural and urban citizens, urban and non-reporter private sector, urban professionals, rural and non-reporter first response, and non-reporter academic users than the US. These findings suggest that the relationships between community type, country, and stakeholder group effect CSN structure and therefore warning capacity. For example, it is possible that BC's greater rural user presence explains the CSN's first responder numbers and why their ties are more inclusive than other groups, as rural users may form smaller, closer-knit communities. However, inferential analysis with larger samples is needed to confirm whether relationships between group geography and network structure correlate.

**Table 4.8 Community Stakeholders Controlled by Country**

| | Country | Aca I. | Citizen | FirstResp | Govt | Hobby | Media | PrivSec | Pro | PubSec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N/A | CAN | 9 | 79 | 9 | 3 | 6 | 13 | 24 | 21 | 9 | 173 |
| | % Row | 5.2% | 45.7% | 5.2% | 1.7% | 3.5% | 7.5% | 13.9% | 12.1% | 5.2% | 100.0% |
| | % Col | 64.3% | 50.6% | 75.0% | 27.3% | 46.2% | 35.1% | 66.7% | 52.5% | 50.0% | 51.3% |
| | USA | 5 | 77 | 3 | 8 | 7 | 24 | 12 | 19 | 9 | 164 |
| | % Row | 3.0% | 47.0% | 1.8% | 4.9% | 4.3% | 14.6% | 7.3% | 11.6% | 5.5% | 100.0% |
| | % Col | 35.7% | 49.4% | 25.0% | 72.7% | 53.8% | 64.9% | 33.3% | 47.5% | 50.0% | 48.7% |
| | Total | 14 | 156 | 12 | 11 | 13 | 37 | 36 | 40 | 18 | 337 |
| | % Row | 4.2% | 46.3% | 3.6% | 3.3% | 3.9% | 11.0% | 10.7% | 11.9% | 5.3% | 100.0% |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Rural | CAN | 7 | 58 | 15 | 18 | 10 | 13 | 19 | 18 | 8 | 166 |
| | % Row | 4.2% | 34.9% | 9.0% | 10.8% | 6.0% | 7.8% | 11.4% | 10.8% | 4.8% | 100.0% |
| | % Col | 77.8% | 75.3% | 83.3% | 66.7% | 71.4% | 76.5% | 57.6% | 54.5% | 80.0% | 69.7% |
| | USA | 2 | 19 | 3 | 9 | 4 | 4 | 14 | 15 | 2 | 72 |
| | % Row | 2.8% | 26.4% | 4.2% | 12.5% | 5.6% | 5.6% | 19.4% | 20.8% | 2.8% | 100.0% |
| | % Col | 22.2% | 24.7% | 16.7% | 33.3% | 28.6% | 23.5% | 42.4% | 45.5% | 20.0% | 30.3% |
| | Total | 9 | 77 | 18 | 27 | 14 | 17 | 33 | 33 | 10 | 238 |
| | % Row | 3.8% | 32.4% | 7.6% | 11.3% | 5.9% | 7.1% | 13.9% | 13.9% | 4.2% | 100.0% |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Urban | CAN | 30 | 249 | 37 | 50 | 29 | 85 | 112 | 140 | 27 | 759 |
| | % Row | 4.0% | 32.8% | 4.9% | 6.6% | 3.8% | 11.2% | 14.8% | 18.4% | 3.6% | 100.0% |
| | % Col | 51.7% | 59.1% | 71.2% | 51.5% | 49.2% | 43.4% | 60.2% | 61.1% | 45.8% | 55.9% |
| | USA | 28 | 172 | 15 | 47 | 30 | 111 | 74 | 89 | 32 | 598 |
| | % Row | 4.7% | 28.8% | 2.5% | 7.9% | 5.0% | 18.6% | 12.4% | 14.9% | 5.4% | 100.0% |
| | % Col | 48.3% | 40.9% | 28.8% | 48.5% | 50.8% | 56.6% | 39.8% | 38.9% | 54.2% | 44.1% |
| | Total | 58 | 421 | 52 | 97 | 59 | 196 | 186 | 229 | 59 | 1357 |
| | % Row | 4.3% | 31.0% | 3.8% | 7.1% | 4.3% | 14.4% | 13.7% | 16.9% | 4.3% | 100.0% |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Total | CAN | 46 | 386 | 61 | 71 | 45 | 111 | 155 | 179 | 44 | 1098 |
| | % Row | 4.2% | 35.2% | 5.6% | 6.5% | 4.1% | 10.1% | 14.1% | 16.3% | 4.0% | 100.0% |
| | % Col | 56.8% | 59.0% | 74.4% | 52.6% | 52.3% | 44.4% | 60.8% | 59.3% | 50.6% | 56.8% |
| | USA | 35 | 268 | 21 | 64 | 41 | 139 | 100 | 123 | 43 | 834 |
| | % Row | 4.2% | 32.1% | 2.5% | 7.7% | 4.9% | 16.7% | 12.0% | 14.7% | 5.2% | 100.0% |
| | % Col | 43.2% | 41.0% | 25.6% | 47.4% | 47.7% | 55.6% | 39.2% | 40.7% | 49.4% | 43.2% |
| | Total | 81 | 654 | 82 | 135 | 86 | 250 | 255 | 302 | 87 | 1932 |
| | % Row | 4.2% | 33.9% | 4.2% | 7.0% | 4.5% | 12.9% | 13.2% | 15.6% | 4.5% | 100.0% |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Nevertheless, rural, urban and non-reporter follower ties elaborate on warning capacity (Table 4.9). US node and edge pairs and connected components are weaker than BC's, but density is marginally better. Centrality measures are similar for both. Thus, BC has more one-on-one or small world sharing while the US has a wider broadcast range. By community type, US non-reporters have slightly higher ratio and lower component sizes. Their centrality measures are weak. BC non-reporters have stronger ratios, more weaker components, worse centrality and equal density. Neither subgroup has strong internal sharing, cross-group bridging, or coordination ability. BC non-reporters are isolated without US ties to connect them in to the CSN. However, their components boost US non-reporter communication throughout the CSN in return. Thus, both groups communicate better together than they do individually, which is a resounding point in favour of leveraging users across the entire CSN for information dissemination to local areas in BC.

**Table 4.9 Community Network Comparisons Controlled by Country**

| | CAN | | | | USA | | | | CSN | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Group* | Rural | Urban | N/A | All | Rural | Urban | N/A | All | Rural | Urban | N/A | All |
| *N.* | 123 | 536 | 107 | 963 | 53 | 477 | 113 | 648 | 199 | 1146 | 266 | 1611 |
| *E.* | 322 | 3107 | 46 | 5347 | 32 | 1897 | 123 | 3222 | 357 | 5132 | 295 | 9687 |
| *Nr* | 0.526 | 0.235 | 0.314 | 0.262 | 0.185 | 0.197 | 0.151 | 0.184 | 0.481 | 0.218 | 0.118 | 0.214 |
| *Er* | 0.689 | 0.381 | 0.478 | 0.415 | 0.313 | 0.329 | 0.262 | 0.310 | 0.650 | 0.358 | 0.211 | 0.352 |
| *CC* | 6 | 2 | 7 | 2 | 5 | 4 | 2 | 3 | 10 | 5 | 6 | 4 |
| *MN* | 89 | 513 | 22 | 764 | 11 | 428 | 68 | 639 | 74 | 192 | 72 | 1605 |
| *ME* | 313 | 3106 | 29 | 5346 | 21 | 1892 | 121 | 3219 | 101 | 946 | 184 | 9683 |
| *DC* | 0.331 | 0.872 | 0.345 | 0.503 | 0.217 | 0.945 | 0.281 | 0.507 | 0.185 | 0.523 | 0.743 | N/A |
| *BC* | 3.499 | 2.889 | 2.655 | 2.944 | 1.414 | 3.263 | 2.503 | 2.965 | 3.665 | 3.448 | 2.359 | 2.82 |
| *d* | 0.021 | 0.011 | 0.004 | 0.006 | 0.012 | 0.008 | 0.010 | 0.008 | 0.009 | 0.004 | 0.004 | 0.004 |

On their own, US and BC urban users have similar ratios, fewer and better connected components than the CSN total, substantially stronger centrality, better betweeness, and higher densities. Canadians are better knit and have higher reciprocity. Otherwise, both countries disseminate warnings well internally and operate better on their own as independent subgroups. In comparison, US rural users have weaker ratios, fewer and weaker components, similar centrality, and higher density than the CSN total. BC rural users have larger ratios, more and stronger components, higher centraliy, and the highest density and betweeness of all. The majority of well-knit rural Canadians suggests stronger group familiarity and cohesion whereas US rural users are the best bridge of all groups. In all, rural users have the highest node and edge pair ratios. They also have the most connected componenents, which are moderately strong. Their centrality is very low and their betweenness and density are higher than most other groups. Thus, rural users are the best internally connected group, but the weakest bridge or external communicater. It is notable that socially and geographically isolated users are also the most tightly tied.

Lastly, community subgroup densities above CSN totals indicate subgroups that are closer knit than the stakeholder group is overall (Figure 4.7). To this end, all BC rural groups are closer knit except first responders. Urban government, first response, media, and public sector are closer knit as well, as are non-reporter academic, citizen, first responder, and media users. In the US, rural government and private sector users are closer knit, as are urban government and hobbyist and non-reporter government and media groups. The data interestingly suggest community-bound stakeholders form small-world groups that are likely familiar and communicate closely, especially rural users in BC, suggesting again that these remote communites are better known to each other than the CSN overall. Again, deeper analysis with larger populations is needed before firm conclusions can be made.

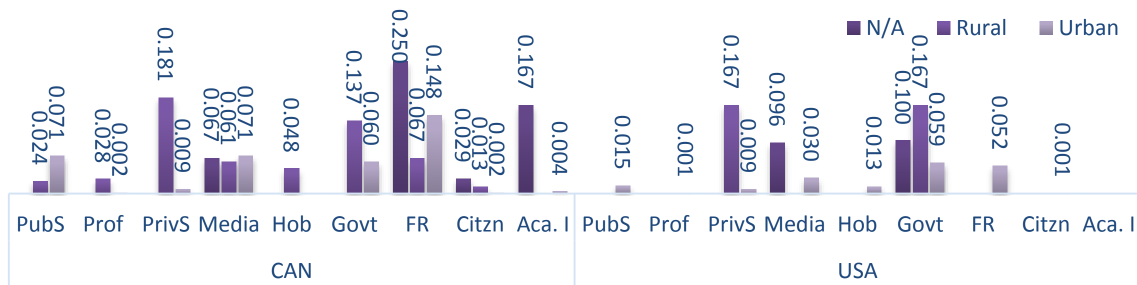



**Figure 4.7 Urban, Rural, and No Location Reported Stakeholder Group Densities**

In all, BC's groups and communities are more insular. Non-reporters are not broadcasters, coordinators, or bridges but are tied to many sources. They are *information seekers*, likely due to a high citizen base. Urban users are *broadcasters,* with high closeness indicating external reach. Rural users are *coordinators.* Their internal communication and reciprocity is strong. In all, BC's part of the CSN is most condusive to *seeking* because of its lower interconnectivity to the US. BC rural and urban users function better independently but their capacity to warn network wide is limited. This means highly specified audience targetting is needed for their networks to warn, such as knowing where users in advance. A more efficient method would be to increase paths between urban broadcasters and rural coordinators to enhance information flow, but this would require BC's network to actively work on making strategic and mutual connections to poorly tied subsets and areas.

## 4.5. Opinion Leader Subnetwork

Lastly, the CSN's opinion leaders (OLs) are an independent subgroup. There were too few to conduct a seperate stakeholder group, country, or commuity network analysis. Furthermore, these data would only show how OLs communicate with each other, which does not clarify their ability to influence non-OLs. However, OL descriptive attributes do show more government, media, and first response, and fewer citizens and professionals compared to the CSN (Figure 4.8). Furthermore, media, government, and first response were mostly Tier 1 or 2 OLs, the top 10% strongest influencers in the network. Academics, hobbyists, professionals, and public and private sector users were mostly in Tiers 3 to 4, while Tier 5, the least influential, was mainly citizens or professionals. Thus, OL status increased membership odds and influence strength in groups with traditional ties to disaster warning, while decreasing likelihoods for groups bearing less responsibility.

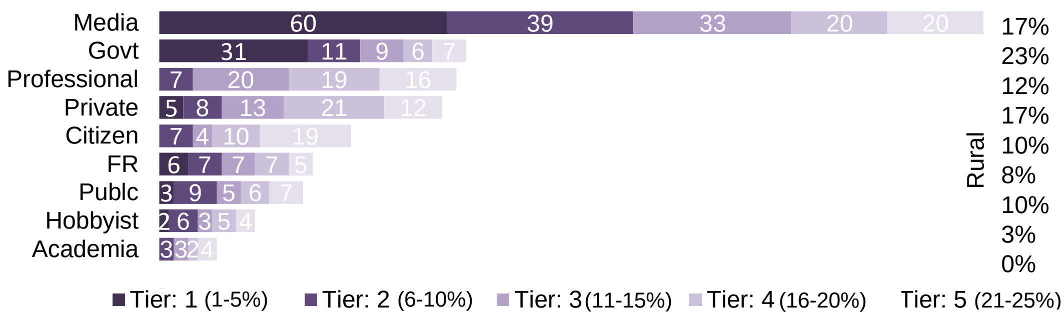



**Figure 4.8 CSN OL Stakeholders by Influence Tier with Percent Rural**

**Table 4.10 OL vs. Non-OL SGs by Country and Community Type**

| | Status | Aca I. | Citizen | FR | Govt | Hobby | Media | Priv Sec | Pros | Pub Sec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CAN | CSN | 41 | 359 | 35 | 42 | 36 | 32 | 118 | 146 | 24 | 833 |
| | %Col | 89.1% | 93.0% | 57.4% | 59.2% | 80.0% | 28.8% | 76.1% | 81.6% | 54.5% | 75.9% |
| | OL | 5 | 27 | 26 | 29 | 9 | 79 | 37 | 33 | 20 | 265 |
| | %Col | 10.9% | 7.0% | 42.6% | 40.8% | 20.0% | 71.2% | 23.9% | 18.4% | 45.5% | 24.1% |
| | Total | 46 | 386 | 61 | 71 | 45 | 111 | 155 | 179 | 44 | 1098 |
| | %Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| USA | CSN | 28 | 254 | 14 | 30 | 30 | 47 | 78 | 94 | 33 | 608 |
| | %Col | 80.0% | 94.8% | 66.7% | 46.9% | 73.2% | 33.8% | 78.0% | 76.4% | 76.7% | 72.9% |
| | OL | 7 | 14 | 7 | 34 | 11 | 92 | 22 | 29 | 10 | 226 |
| | %Row | 3.1% | 6.2% | 3.1% | 15.0% | 4.9% | 40.7% | 9.7% | 12.8% | 4.4% | 100.0% |
| | %Col | 20.0% | 5.2% | 33.3% | 53.1% | 26.8% | 66.2% | 22.0% | 23.6% | 23.3% | 27.1% |
| | Total | 35 | 268 | 21 | 64 | 41 | 139 | 100 | 123 | 43 | 834 |
| | %Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Non-Reporter | CSN | 10 | 146 | 4 | 8 | 11 | 14 | 29 | 33 | 14 | 269 |
| | % Col | 71.4% | 93.6% | 33.3% | 72.7% | 84.6% | 37.8% | 80.6% | 82.5% | 77.8% | 79.8% |
| | OL | 4 | 10 | 8 | 3 | 2 | 23 | 7 | 7 | 4 | 68 |
| | % Col | 28.6% | 6.4% | 66.7% | 27.3% | 15.4% | 62.2% | 19.4% | 17.5% | 22.2% | 20.2% |
| | Total | 14 | 156 | 12 | 11 | 13 | 37 | 36 | 40 | 18 | 337 |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Rural | CSN | 9 | 71 | 13 | 13 | 12 | 7 | 23 | 26 | 4 | 178 |
| | % Col | 100.0% | 92.2% | 72.2% | 48.1% | 85.7% | 41.2% | 69.7% | 78.8% | 40.0% | 74.8% |
| | OL | 0 | 6 | 5 | 14 | 2 | 10 | 10 | 7 | 6 | 60 |
| | % Col | 0.0% | 7.8% | 27.8% | 51.9% | 14.3% | 58.8% | 30.3% | 21.2% | 60.0% | 25.2% |
| | Total | 9 | 77 | 18 | 27 | 14 | 17 | 33 | 33 | 10 | 238 |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Urban | CSN | 50 | 396 | 32 | 51 | 42 | 57 | 144 | 181 | 39 | 992 |
| | % Col | 86.2% | 94.1% | 61.5% | 52.6% | 71.2% | 29.1% | 77.4% | 79.0% | 66.1% | 73.1% |
| | OL | 8 | 25 | 20 | 46 | 17 | 139 | 42 | 48 | 20 | 365 |
| | % Row | 2.2% | 6.8% | 5.5% | 12.6% | 4.7% | 38.1% | 11.5% | 13.2% | 5.5% | 100.0% |
| | % Col | 13.8% | 5.9% | 38.5% | 47.4% | 28.8% | 70.9% | 22.6% | 21.0% | 33.9% | 26.9% |
| | Total | 58 | 421 | 52 | 97 | 59 | 196 | 186 | 229 | 59 | 1357 |
| | % Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| Total | CSN | 69 | 613 | 49 | 72 | 66 | 79 | 196 | 240 | 57 | 1441 |
| | %Col | 85.2% | 93.7% | 59.8% | 53.3% | 76.7% | 31.6% | 76.9% | 79.5% | 65.5% | 74.6% |
| | OL | 12 | 41 | 33 | 63 | 20 | 171 | 59 | 62 | 30 | 491 |
| | %Col | 14.8% | 6.3% | 40.2% | 46.7% | 23.3% | 68.4% | 23.1% | 20.5% | 34.5% | 25.4% |
| | Total | 81 | 654 | 82 | 135 | 86 | 250 | 255 | 302 | 87 | 1932 |
| | %Col | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

Additionally, OLs were divided more evenly by country than the CSN and had fewer non-reporter, equivalent rural, and more urban users (Table 4.10). BC urban first response, rural hobbyist and private sector, and non-reporter citizen and public sector, and US urban government OLs increased. Community types did not differ widely from the CSN in total, but US urban and BC rural OLs increased. Non-reporters were reduced by decreased professional, citizen, and private and public sector users in the OL subgroup (Figure 4.10). The increase in first responders, media, and government also likely caused the increase in BC rural and US urban OLs. Thus, greater group differentiation, incidence of influence in disaster warning groups, and variance in community type within countries indicates that OLs are not only more inclined to provide identifying profile information for stakeholder group assignment, they are also an important and distinct subgroup from the CSN.

## 4.6. Boundary Benefits

In this chapter, NTWC was shown as a global global network in which the CSN is a highly active subset. Although the CSN has minimal end-to-end warning capacity, stakeholder group, country, and community subsets express distinct but limited capacities. While the CSN is mostly urban, BC has more rural users, the US has more urban users, and both countries have equal non-reporters. BC has more citizen, professional, private sector, and first response, and the US trends towards having more media users. Each subgroup has different early warning strengths. Government, media, and BC urban users are *boosters*. Academics, professionals, and hobbyists are *brokers*. First response, public sector, and BC rural users are *coordinators*. Private sector, citizens, and BC non-reporters are *seekers*. By studying stakeholders in this way it is possible to gague how groups effect warning reach, accuracy, and authenticity. In particular, stakeholder groups show greater capacity when they have a community type in common. Thus, the CSN is constructed of numerous small-world communities that interconnect relative to shared or interoperable roles users fill in disaster mitigation, which would explain why the CSN has poor network wide communication overall but better communication within and between subgroups. The CSN's OLs are also a distinct subgroup marked by stronger mutual communication capacity and more influential users in emergency management.

The data also inform on groups that could be brought more into the CSN's fold. More academic, hobbyist, and private sector representation is needed. Disconnected bridge or seeker groups, especially citizens who are mostly isolates yet make up the vast majority of the CSN, need to be more deeply integrated so that they can access more sources and disseminate warnings further. That most users are urban fits with Anderson's (2006) finding that rural areas lack infrastructure to support social media communities. However, it is critical to acknowledge rural users are present, and that the majority are located in vulnerable tsunami notification zones. Rural users are key contact points whose value in leveraging local networks in the event of an emergency should not be overlooked. It is unknown where non-reporter users are relative to risk, but this minority too cannot be discounted. Whatever reasons non-reporters have to avoid disclosing location, as a group they are well positioned to transfer information between BC and US stakeholder groups, and will likely contribute to the broaden spread of warning information across the CSN. Lastly, in the event of a tsunami, even if not directly impacted, urban users will be vital. There are significantly more urban eyes and ears on NTWC, and that means a greater likelihood of seeing a warning in this group. Rural users also have access to far fewer information sources. They can benefit from urban users' external reach to gain access to outside information, amplify messages and bridge content to groups who may need it, thereby fascilitating interoperability between stakeholder groups. For this reason, it is quite unfortunate that ties between urban and rural users are lacking as their ability to cross-share is subsequently limited. These relationships should be highly encouraged.

In all, the story the CSN tells us, and what the network analytic tools used to pull those insights provide, is about knowing and accomodating boundaries. That there is room to improve warning capacity along the Pacific Northwest and particularly for British Columbia is certain. Greater connectivity to and inclusion of rural areas, and better integration with lower density stakeholder groups would benefit the CSN as well. That said, stakeholder subcommunities may be more known to each other than the surface CSN metrics can reveal and, in the case of the tightly knit rural subgroupings or OLs, may be able to at least transmit to personal contacts even if wider coordination capacity is limited. As such, this social network analysis can only show how communication lines within and between stakeholder groups are structured at a high level. It pinpoints areas for developing paths, such between BC's rural first responder and lay users, from a holistic rather than localized perspective. These findings can be used in repeat studies to aid in evaluating the quality of connectivity over time between rural and urban or Canadian and US stakeholders. Thus, despite its limitations, a social network analysis approach can nevertheless help maximize targetted tsunami warning dissemination speed and efficacy by assessing warning ability in terms of interoperability expressed through a group's quantity of ties.

# Chapter 5.

# Survey Findings: Matters of Influence

A survey was designed to ascertain whether the CSN's influential opinion leaders (OLs) consider themselves able to warn. This chapter details those results. It starts by comparing network observed and OL self-reported stakeholder groups (SG) and locations to check the profile content analysis' accuracy. Next, network and reported influence are compared to validate the CSN calculation's accuracy and to assess which OLs are influential weak ties. Differences across stakeholder group, country, community, coastal access, and in-degree are discussed in the context of hashtag and content control preferences, usage patterns, motivations for participating in the CSN, and benefits and limitations of Twitter in tsunami warning. These findings qualify the CSN's warning access to BC by showing how OLs think about and use Twitter.

To start, Table 5.1 compares assigned and reported stakeholder groups and locations for survey participants. The "CSN" column includes all OLs from the network analysis, "OL" contains assigned metrics for the 121 OLs who took the survey, and "Survey" contains their self-report data for the same variables. "Match" indicates the total OLs who reported the same group or municipality assigned during the CSN analysis.

**Table 5.1 CSN and Survey OL Location and SG Chi-Square Goodness of Fit**

| **Location** | CSN | %Row | OL | %Row | Survey | %Row | Match | %Row | $X^2$ | $p \le .05$ |
|---|---|---|---|---|---|---|---|---|---|---|
| **BC** | 265 | 54% | 79 | 65% | 80 | 66% | 54 | 68% | 1.2 | 0.273 |
| *Rural* | 46 | 77% | 14 | 82% | 13 | 81% | 11 | 85% | 0.057 | 0.811 |
| *Urban* | 184 | 51% | 58 | 65% | 67 | 64% | 43 | 64% | 1.47 | 0.225 |
| **US** | 226 | 46% | 39 | 32% | 51 | 34% | 29 | 71% | 1.8 | 0.18 |
| *Rural* | 14 | 23% | 3 | 18% | 3 | 20% | 0 | 0% | 0.209 | 0.647 |
| *Urban* | 179 | 49% | 31 | 35% | 38 | 36% | 29 | 76% | 1.988 | 0.159 |
| **Total Rural** | 60 | 13% | 17 | 14% | 16 | 13% | 11 | 69% | .03 | .862 |
| **Total Urban** | 363 | 77% | 89 | 74% | 105 | 87% | 72 | 69% | 1.32 | .251 |
| *Total* | 491 | 100% | 121 | 100% | 121 | 100% | 83 | 69% | --- | --- |
| **Stakeholders (Survey groups recoded into CSN groups)** | | | | | | | | | | |
| *Media* | 171 | 35% | 28 | 23% | 73 | 36% | 24 | 86% | 20.05 | .001* |
| *Govt.* | 20 | 13% | 20 | 17% | 37 | 18% | 14 | 70% | 5.07 | .0245* |
| *FirstResp.* | 33 | 7% | 10 | 8% | 21 | 10% | 8 | 80% | 3.333 | .068 |
| *PrivSec* | 59 | 12% | 11 | 9% | 9 | 4% | 2 | 18% | 0.48 | .827 |
| *PubSec* | 30 | 6% | 12 | 10% | 15 | 7% | 4 | 33% | 0.043 | .835 |
| *Hobby* | 20 | 4% | 5 | 4% | 7 | 3% | 2 | 40% | 0.091 | .763 |
| *Cits/Pros* | 103 | 21% | 29 | 24% | 34 | 17% | 17 | 59% | 1.471 | .225 |
| *Aca.I.* | 12 | 2% | 6 | 5% | 6 | 3% | 6 | 100% | 0 | 1 |
| *Total* | 491 | 100% | 121 | 100% | 202 | 100% | 77 | 64% | --- | --- |

Notably, SG assignments were 64% accurate. They were at least 70% so for academics, government, first response, and media, but private and public sector detection was poor. Perhaps the content analysis failed for these groups or interpretive differences produced false negatives. However, Chi-square goodness of fit tests ($\alpha$ = .05, *df* = 1) found no difference between and reported and assigned SGs save government and media, likely because more OLs chose these groups than was predicted. Row percentages for “CSN” and “Survey” are also almost exact except for a large drop in private sector and small jumps in first response and government. In addition, no significant differences between assigned and reported countries or community types were observed. However, assigned and reported municipalities only matched in 69% of cases, although BC rural OLs were 85% and US urban OLs were 71% matched. Because all respondents provided a location, non-reporters in the CSN were not included in the table. However, because there was no change in assigned and reported rural counts but a slight increase in reported urban OLs, it is likely non-reporter OLs live in urban areas. In all, the CSN’s aggregate data appear to reliably compare to self-reported country or provincial and state locations. Furthermore, given the high rates of success with some stakeholder groups and municipalities, the possibility that a refined content analysis could also yield more accurate municipality and stakeholder group assignments is promising. That BC rural OLs in particular share municipality information implies this subset prioritizes location data for disaster response.

## 5.1. The Strength of Weak Ties

Opinion leaders who are loosely tied to the CSN recall a simplified version of Granovetter’s (1973) strength-of-weak-ties principle. It states that strong ties form community structures and weak ties are points where new information can enter and exit. However, being loosely connected is not enough; a true weak tie must also be influential in order to ensure content passed on is disseminated. Thus, OLs with an in-degree of 10 or less represent the CSN’s weak ties who may access networks that contain or can reach locals in BCs at-risk areas, especially those who are highly influential. The survey responses show most OLs saw themselves as influential. However, those in Tier 1 and 2 for network influence opined they were more influential regardless of in-degree, whereas more isolates and low in-degree OLs in Tiers 3 to 5 saw themselves as less influential (Figure 5.1). This pattern suggests

**Figure 5.1 Survey Influence by Tier**

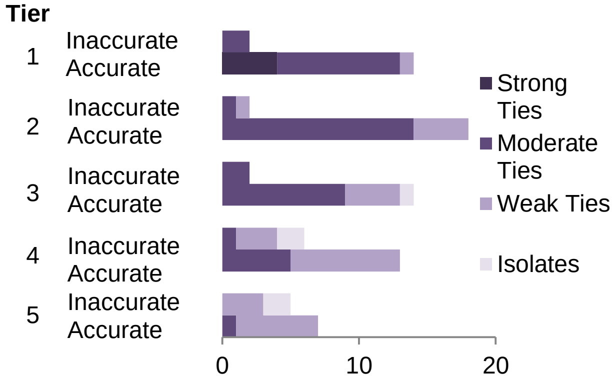



**Table 5.2 Influence Correlation**

| | | Observed | Reported |
|---|---|---|---|
| Assigned Influence (CSN) | Pearson *R* | 1 | -.263** |
| | Sig. (1-tailed) | | .002 |
| | Sum of Squares | 5352.810 | -202.203 |
| | Covariance | 44.607 | -1.728 |
| | N | 121 | 118 |
| Reported Influence (Survey) | Pearson *R* | -.263** | 1 |
| | Sig. (1-tailed) | .002 | |
| | Sum of Squares | -202.203 | 119.157 |
| | Covariance | -1.728 | .993 |
| | N | 118 | 121 |

**. Correlation is significant at 0.01 level (1-tailed).

the probability that an OL will be loosely connected or an isolate rises as influence drops, meaning that highly influential or true weak ties are rarer than strong ties. Furthermore, there is a significant negative correlation between assigned and self-reported influence ($r = -.263$, $n = 121$, $p = .002$). In the CSN smaller scores indicate higher influence, so network influence increases alongside perceived influence (Table 5.2). Recall that different metrics measure different kinds of influence, and changing a network's inclusion criteria changes which users appear influential (Cha et. al, 2010; Dubois & Gaffney, 2014). The CSN's method resolves this inconsistency by measuring influence using ranked averages from multiple Twitter metrics constrained by location. In this, it has successfully produced a new method for OL detection, setting an empirical precedent that warrants rigorous testing.

This correlation means OL responses qualify country, community, coastal access, and in-degree differences in CSN warning for BC. Overall, 61% of OLs agreed they were somewhat to strongly influential (Table 5.3). Coastal access had no effect on these ratings. BC reported less influence than the US, although rural OLs rated themselves higher than urban OLs. US OLs amplified this pattern. Rural OLs unanimously agreed they were influential. Urban OLs ranked lower, but at 70% agreement still surpassed all BC groups. As such, rural OLs rated themselves higher than urban OLs regardless of country, and US OLs rated themselves higher overall.

**Table 5.3 High Reported OL Influence by Strong and Weak In-Degree**

| | Strong Ties | | | Weak Ties | | | All Ties | | |
|---|---|---|---|---|---|---|---|---|---|
| **Group** | ***n*** | **Agree** | **%Row** | ***n*** | **Agree** | **%Row** | ***n*** | **Agree** | **%Row** |
| CAN | 48 | 33 | 67% | 33 | 11 | 33% | 81 | 44 | 53% |
| *Rural* | *8* | *6* | *75%* | *5* | *2* | *40%* | *13* | *8* | *62%* |
| *Urban* | *40* | *27* | *68%* | *28* | *9* | *31%* | *68* | *36* | *53%* |
| US | 15 | 11 | 73% | 25 | 18 | 72% | 40 | 29 | 73% |
| *Rural* | *2* | *2* | *100%* | *1* | *1* | *100%* | *3* | *3* | *100%* |
| *Urban* | *13* | *9* | *69%* | *24* | *17* | *71%* | *37* | *26* | *70%* |
| All Rural | 10 | 8 | 80% | 6 | 3 | 50% | 16 | 11 | 79% |
| All Urban | 53 | 36 | 68% | 52 | 26 | 50% | 105 | 62 | 59% |
| Coastal | 51 | 37 | 70% | 41 | 20 | 48% | 92 | 57 | 62% |
| NCoastal | 13 | 8 | 58% | 16 | 10 | 63% | 29 | 18 | 61% |
| Total | *63* | *44* | *70%* | *58* | *29* | *50%* | 121 | 73 | 61% |

Moreover, OL responses contained near equal amounts of strong (63) and weak (58) ties, indicating an even chance of in-degree influence across country, community, and coastal access. Regardless, strong ties were much more likely to be influential. Influential weak tie OLs were equally rare across urban and rural locales, evenly divided with influential strong tie OLs in the US, radically reduced in BC, and increased in non-coastal locations. In all, rural status was a strong predictor of influence, followed by US location, while being located near tsunami risk was not. By extension, non-coastal status was a strong predictor of influential weak ties, followed by US location, while community type was not. As such, in BC rural OLs are best able to prompt others to share warnings in BC, and non-coastal OLs are more likely to extend influence outside the CSN, but in both cases not nearly as well as US OLs overall. BC's surprising dearth suggests influence is lessened greatly compared to the US, particularly for external reach but less so within the CSN.

Influence agreement among strong and weak tie OLs also differed by stakeholder group (Table 5.4). In all, traditional media agreed most, followed by public sector, social media, other, first response, and private sector OLs. Government and technologists reported average influence, and lay and hobbyist OLs rated lowest. Social media, government, hobbyist, other, and lay OLs had more influential strong ties whereas technologist, public, and private sector OLs had more influential weak ties. Traditional media and first response were split evenly. Cases were too low to make firm conclusions about rural and urban influential weak tie differences for all stakeholder groups and repeated study is needed to ensure these findings' accuracy. However, a tentative conclusion can be made. The elevated presence of influential weak tie OLs in the private and public sectors, as well as traditional media and first response, implies these groups are more able to disseminate to outside networks, while social media, government, hobbyist, other, and lay OLs have greater influence within the CSN. If so, US OL's higher

**Table 5.4 SG Tie Influence**

| Group | Total | Agree | %Col |
|---|---|---|---|
| *T. Media* | *30* | *24* | *80%* |
| Strong | 21 | 17 | 81% |
| Weak | 9 | 7 | 78% |
| *S. Media* | *37* | *28* | *76%* |
| Strong | 23 | 19 | 83% |
| Weak | 14 | 9 | 64% |
| *Pub. Sector* | *13* | *10* | *77%* |
| Strong | 6 | 4 | 67% |
| Weak | 7 | 6 | 86% |
| *FirstResp.* | *21* | *14* | *67%* |
| Strong | 15 | 10 | 67% |
| Weak | 6 | 4 | 67% |
| *Government* | *38* | *23* | *61%* |
| Strong | 25 | 17 | 68% |
| Weak | 13 | 6 | 46% |
| *Technologist* | *5* | *3* | *60%* |
| Strong | 1 | 0 | 0% |
| Weak | 4 | 3 | 75% |
| *Hobbyist* | *7* | *4* | *57%* |
| Strong | 3 | 2 | 67% |
| Weak | 4 | 2 | 50% |
| *Priv. Sector* | *9* | *6* | *67%* |
| Strong | 4 | 2 | 50% |
| Weak | 5 | 4 | 80% |
| *Other* | *8* | *6* | *75%* |
| Strong | 2 | 2 | 100% |
| Weak | 6 | 4 | 67% |
| *None* | *31* | *13* | *42%* |
| Strong | 10 | 5 | 50% |
| Weak | 21 | 8 | 38% |

influence may relate to their greater media presence. Similarly, BC rural OL's higher influence may be attributed to greater private and public sector and first response OL presence in BC rural communities. As such, these groups are vital sources for BC's few influential weak ties to access BC communities outside the CSN.

## 5.2. From Neighborhood to Network

OL country, community, coastal access, in-degree, and stakeholder group differences also impact warning capacity for BC (Table 5.5). Two thirds of OLs were in BC, three quarters were coastal, half were weak ties, and only 13% were rural. Almost two thirds were affiliated with emergency management through traditional media, government, the public sector, or first response. Most were involved in social media and government, followed by citizens and traditional media, first response, public, private sector and other, hobbyist, and technologist groups. BC had more first response and lay OLs, equal government, fewer other groups, and fewer OLs in traditional emergency management compared to the US. All groups had more urban than rural OLs except government, but proportionately more rural OLs were in emergency management. More traditional media and lay OLs and fewer hobbyist, first response, technologist, private sector and other OLs were coastal. Coastal access had no effect on involvement in emergency management, but fewer weak ties were involved in emergency management groups than strong tie OLs.

**Table 5.5 Survey SGs by Country, Community, Coast Access, and In-Degree**

| Group | TMedia | SoMe | PubS | FR | Govt | Tech | Hobby | PrivS | Other | None | EMO | N-EMO | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Can | 17 | 19 | 5 | 15 | 25 | 1 | 3 | 4 | 3 | 24 | 49 | 31 | 80 |
| % Col | 21% | 24% | 6% | 19% | 31% | 1% | 4% | 5% | 4% | 30% | 61% | 39% | 66% |
| US | 14 | 19 | 10 | 6 | 12 | 3 | 4 | 5 | 5 | 8 | 27 | 14 | 51 |
| % Col | 34% | 46% | 24% | 15% | 29% | 7% | 10% | 12% | 12% | 20% | 66% | 34% | 34% |
| Rural | 3 | 5 | 1 | 2 | 7 | 0 | 0 | 1 | 0 | 4 | 11 | 5 | 16 |
| % Col | 19% | 31% | 7% | 13% | 44% | 0% | 0% | 6% | 0% | 25% | 69% | 31% | 13% |
| Urban | 28 | 33 | 14 | 19 | 30 | 4 | 7 | 8 | 8 | 28 | 65 | 40 | 105 |
| % Col | 27% | 31% | 93% | 18% | 29% | 4% | 7% | 8% | 8% | 27% | 62% | 38% | 87% |
| Coast | 25 | 30 | 12 | 15 | 28 | 2 | 3 | 6 | 5 | 28 | 58 | 35 | 92 |
| % Col | 27% | 32% | 13% | 16% | 30% | 2% | 3% | 7% | 5% | 30% | 62% | 38% | 76% |
| NCoast | 6 | 8 | 3 | 6 | 8 | 2 | 4 | 3 | 3 | 4 | 17 | 10 | 29 |
| % Col | 22% | 30% | 11% | 22% | 30% | 7% | 15% | 11% | 11% | 15% | 63% | 37% | 24% |
| Strong | 21 | 23 | 6 | 16 | 25 | 1 | 3 | 5 | 2 | 11 | 51 | 13 | 63 |
| % Col | 33% | 36% | 9% | 25% | 39% | 2% | 5% | 8% | 3% | 17% | 80% | 20% | 52% |
| Weak | 10 | 15 | 9 | 5 | 12 | 3 | 4 | 4 | 6 | 21 | 25 | 32 | 58 |
| % Col | 18% | 26% | 16% | 9% | 21% | 5% | 7% | 7% | 11% | 37% | 44% | 56% | 48% |
| Total | 31 | 38 | 15 | 21 | 37 | 4 | 7 | 9 | 8 | 32 | 76 | 45 | 121 |
| % Row | 26% | 31% | 12% | 17% | 31% | 3% | 6% | 7% | 7% | 26% | 63% | 37% | 100% |

Respondents knew of their importance to tsunami warning and were hazard aware (Table 5.6). Half used their accounts for work, a third were personal, and only a fraction were for research or study. About 15% cited other or dual uses, often personal and work, activism, or volunteering. About half followed NTWC to monitor local bulletins, send bulletins to the public, fulfill general interests, or send bulletins to people they knew. The other half followed NTWC for all of these and a minutia for other reasons. The latter included two or more but not all options, or following NTWC as part of their jobs. A full 80% considered Twitter important for tsunami warning. Around two thirds were confident in their general or earthquake and tsunami hazard awareness. Hazard awareness, Twitter esteem, stakeholder diversity, willingness to participate, and proximity suggest OLs are primed to disseminate warnings within or into networks that extend to PNC at-risk coasts, even though the CSN and weak-tie data indicate they are not structurally able to do so well in BC.

**Table 5.6 OL Frequencies**

| **Opinion Leader…** | ***f*** | ***% Total*** |
|---|---|---|
| *Lives/Works In*: | | |
| BC | 80 | 66.1% |
| AK, WA, OR, or CA | 41 | 33.9% |
| A rural community | 16 | 13.2% |
| A coastal community | 93 | 76.9% |
| *Main account purpose:* | | |
| Work | 64 | 51.6% |
| Personal | 39 | 31.5% |
| Research | 2 | 1.6% |
| Other | 19 | 15.3% |
| Values Twitter tsunami communication: | | |
| Extremely important | 46 | 38% |
| Important | 51 | 42% |
| Somewhat important | 19 | 16% |
| A little important | 4 | 3% |
| Not important | 0 | 0% |
| *Follows @nws_ntwc to:* | | |
| General interest | 10 | 8.3% |
| Send bulletins to people I know | 5 | 4.1% |
| Send bulletins to public | 19 | 15.7% |
| Monitor my area | 22 | 18.2% |
| All of the above | 61 | 50.4% |
| Other | 4 | 3.3% |
| *Local hazard aware:* | | |
| Accurate | 90 | 74% |
| Somewhat accurate | 24 | 20% |
| Neutral | 4 | 3% |
| Somewhat inaccurate | 3 | 3% |
| Inaccurate | 0 | 0% |
| *Earthquake and tsunami hazard aware:* | | |
| Accurate | 85 | 70% |
| Somewhat accurate | 29 | 24% |
| Neutral | 4 | 3% |
| Somewhat inaccurate | 3 | 3% |
| Inaccurate | 0 | 0% |

Additionally, OLs could access multiple notification sources (Table 5.7). Over two thirds used electronic or print mass media. Half used other social media or Twitter accounts, websites and forums, or email distribution lists. A third had SMS subscriptions, a quarter physical warning systems, like sirens, and a sixth had other options, including: NWS, NOAA, and VHF radio; scanners; smartphone apps; local communication systems or associations like the Juan de Fuca emergency management program; and, rarely, direct access to call lists, EMBC's Provincial Emergency Notification System (PENS), or local authorities. Around 5% reported no extra sources, confirming a subset of OLs solely reliant on NTWC. Furthermore, 65% checked @NWS_NTWC often to all the time so no warning source was held in common more than the CSN itself. In this way, the CSN is a converging space where BC OLs can access an array of users with various roles and skillsets to provide or access warning content from myriad interpersonal or mediated origins.

**Table 5.7 OL Preferences**

| User… | *f* | % |
|---|---|---|
| Hours per week viewing or using Twitter: | | |
| 16+ | 31 | 26% |
| 6 - 15 | 50 | 41% |
| 0 - 5 | 39 | 32% |
| Pays attention to @nws_ntwc: | | |
| All the time | 36 | 30% |
| Often | 44 | 36% |
| Sometimes | 27 | 22% |
| Rarely | 10 | 8% |
| Never | 0 | 0% |
| Has other warning sources: | | |
| Other Twitter accounts | 61 | 50% |
| Email distribution lists | 61 | 50% |
| Websites/Forums | 59 | 49% |
| Other social media | 66 | 55% |
| SMS subscriptions | 44 | 36% |
| Traditional media | 84 | 69% |
| Physical warning system | 32 | 26% |
| Other | 16 | 13% |
| None | 6 | 5% |

Twitter use invariably effects capacity to warn (Table 5.8). In an average week, one third of OLs spent 5 hours or less on Twitter. Almost half spent between 6 to 15 hours. A quarter spent 16 or more, enough for a part-time job. On an average day, 13% tweet disaster content for half or more of their time, and 9% do not tweet at all. Over 40% spend that time interacting, including replying, retweeting, direct messaging, or favouriting. However, 75% said less than a third of those interactions pertained to disasters. Another 75%, viewed content for half or more of their time, but 69% said less than a third of that time was spent on disaster content. The fact that so many OLs work or volunteer in emergency management related fields, report being hazard aware, and view Twitter as important to disaster communication conflicts with how much time they spend viewing content and how little of their Twitter use pertains to disasters.

**Table 5.8 Opinion Leader's Twitter Usage Breakdown**

| On an average day, how much time do you spend on Twitter… | All | % | Most | % | Half | % | Some | % | Little | % | None | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tweeting disaster content | 4 | 3% | 9 | 7% | 4 | 3% | 23 | 19% | 69 | 57% | 11 | 9% |
| General interacting | 3 | 3% | 12 | 10% | 25 | 21% | 46 | 38% | 33 | 27% | 0 | 0% |
| Interactions related to disasters | 8 | 7% | 18 | 15% | 4 | 3% | 31 | 26% | 48 | 40% | 11 | 9% |
| General viewing | 6 | 5% | 55 | 46% | 28 | 23% | 23 | 19% | 8 | 7% | 0 | 0% |
| Views related to disasters | 3 | 3% | 21 | 17% | 12 | 11% | 48 | 40% | 33 | 27% | 2 | 2% |

Lastly, to assess how BC OLs might use Twitter to warn, respondents were asked about their hashtag and content control preferences, and opinions about Twitter benefits and limitations (Table 5.9). Over 25% agreed emergency management should develop, circulate, and regulate hashtags. Under 10% felt hashtags should be developed by publics and circulated reactively, and 60% felt both were needed. In contrast, 15% said content diffusion should be managed. Only 1% felt no control was needed. A full 80% believed both formal and public control was critical. A minority were unsure or preferred neither role in both camps. Overall OLs were more concerned about hashtag than content control. However, that most agreed cooperation with other users was needed and valuable indicates OLs view participation and user agency in Twitter as key to warning success.

**Table 5.9 Twitter Preferences, Benefits, and Limits**

| Twitter usage… | *f* | % total |
|---|---|---|
| Hashtag preferences: | | |
| Formal | 33 | 27% |
| Informal | 8 | 7% |
| Both | 70 | 58% |
| Neither | 3 | 3% |
| Unsure | 7 | 6% |
| Content control preferences: | | |
| Emergency managers only | 19 | 16% |
| Public management only | 1 | 1% |
| Both | 98 | 80% |
| Neither | 3 | 3% |
| Unsure | 0 | 0% |
| Response benefits: | | |
| Early warning system | 111 | 92% |
| Real-time mass notification system | 111 | 92% |
| Real-time local communication system | 90 | 75% |
| Monitoring system for updates | 77 | 64% |
| Public, private, or local authority coord. | 49 | 41% |
| Interoperability for stakeholder groups | 48 | 40% |
| Situational awareness | 93 | 77% |
| Last-mile population access | 46 | 38% |
| Rumor or miscommunication prevention | 88 | 73% |
| Fundraising | 25 | 21% |
| Social support | 42 | 35% |
| Solicit or provide aid | 51 | 42% |
| Other | 7 | 6% |
| None | 0 | 0% |
| Non-response benefits: | | |
| Public safety information | 109 | 90% |
| Increased account followers | 59 | 49% |
| Build relationships with followers | 62 | 51% |
| Prevention/mitigation information | 78 | 65% |
| Disaster preparation information | 90 | 74% |
| Increase hazard and risk awareness | 91 | 75% |
| Identify at-risk populations | 44 | 36% |
| Other | 5 | 4% |
| None | 0 | 0% |
| Tweet limitations: | | |
| Too short | 33 | 27% |
| Fail to reach intended recipients | 85 | 70% |
| Visible to anyone | 2 | 2% |
| Contributed to by anyone | 16 | 13% |
| Not formally authorized | 55 | 46% |
| Exploited by users for popularity | 27 | 22% |
| Misinformation or rumour spread | 83 | 69% |
| Creation cannot be managed | 38 | 31% |
| Other | 13 | 11% |
| None | 5 | 4% |

OLs varied more on Twitter's benefit to disaster communication. During response, most said it could be an early warning or mass notification system. Three quarters thought it could notify locals, dispel rumors, or raise situational awareness. Two-thirds said it could be used for content monitoring. Less than half felt it could support interoperability or solicit or provide aid. About a third said it granted last-mile access or social support. Less than a quarter thought it could be used to raise funds.  A handful stated other benefits, like family or friend reunification and communication, community development, preparedness planning, and trust building. Outside response, most agreed Twitter was useful for public safety communication. Three quarters said the same for preparedness and risk or hazard awareness. Two thirds agreed for prevention and mitigation. Half said it could build or increase follower numbers or relationships. A third felt it could identify at-risk populations. Others cited gaining site intelligence, making announcements, finding collaborators, establishing leaders, managing expectations, crowdsourcing, preventing or clearing misinformation, increasing buy in and stakes for emergency management, and connecting emergency managers to other users.

Opinions about Twitter's limitations were less pronounced. Two-thirds thought the site spread misinformation or failed to find targets. Half had concerns about lack of tweet authorization, as a quarter to a third also did for tweet length, exploitation, or uncontrolled creation. A sixth thought Twitter was *too* public. A tenth saw other obstacles, like: device or infrastructure failure; separating warnings from noise; lost information or timeliness due to tweet spam; confusion; URL added layers to information access; last-mile and target user or follower dearth; traditional media audience bias; overgeneralization; jargon; and, inability to trigger PENS or other notification systems. About 5% of OLs thought Twitter had no limitations for tsunami warning at all, whereas all OLs thought Twitter had benefits, suggesting the platform is viewed favorably despite its noticeable drawbacks.

However, despite the value assigned communication in Twitter to mitigate disasters, most OLs do not tweet, interact over, or view disaster content enough to support its application. Even though tsunamis are infrequent, hazards and disasters occur on the PNC annually, including wildfires, floods, and storms. Many OLs, especially those in media, government, or first response, would be familiar with these so there must be other reasons for this lack of activity. It is interesting that the majority of OLs prefer benefits associated with broadcasting and monitoring, like situational awareness, than with coordinating or interacting, such as detecting at-risk populations. The main limitations identified were that messages would not reach target audiences or contain incorrect information, which suggests these concerns are rooted in how difficult it is to find target audiences on a public medium. As such, perhaps unclear responsibilities, roles or audience access strategies cause OLs, and especially emergency management OLs, not to partake in disaster communication as often. Or, perhaps different cultural practices effect the interest, appropriateness, or desire to communicate via Twitter that requires further inquiry.

## 5.3. Content Management Preferences

To better understand their beliefs about Twitter based tsunami warning, OLs were asked to specify reasons for their hashtag preferences. The 27% who preferred standardization cited control, timeliness, accuracy, trustworthiness, and credibility. They saw hashtags as a start place and official channel for better speed, clarity, stability, reliability, and continuity. Official tags could be advertised, automated, made familiar to users, and allow for testing, training, and process improvement. Oversight enabled monitoring and a known space to quickly locate information. Management helped users know where to look, how to join in, and kept content on-topic, streamlined, meaningful, and separate from noise. Specificity minimized confusion, non-official involvement, and interference. Improved localization, response time, and misinformation removal were expected to result. Proponents also thought ad-hoc hashtags were too diverse, unpredictable, repetitious, easily outdated, variable, emotional instead of factual, and drew attention from official sources and content.

In contrast, the 7% who preferred public creation emphasized flexibility, accessibility, and reach. These OLs thought public hashtags could achieve viral circulation and speed. They iterated how public and organic content was the root of Twitter's culture and purpose, and that restrictions countered the features that made the site useful. They pointed out formal hashtags often are ignored for spontaneous ones that develop around events, and argued informal hashtags circulated earlier and were intuitively more recognizable, relatable, and accessible. This in turn made it easier and faster for users who were not connected to emergency management to find them. For this reason, and because disaster needs are unpredictable, these OLs thought responders should go to publics and use their language and syntax, rather than force communication into a predefined channel. They also stated community self-governance was a solution for inundation and misinformation, stating that the volume and depth of participation fostered accuracy and management informally. A minority were unsure (6%) or felt hashtags were inappropriate (3%), stipulating they were too generic to identify locals, too easily co-opted by those uninvolved in response, and too difficult for lone users to promote, especially without large followings as is the case for many first responders. These OLs focused on what is perhaps the biggest issue with hashtags to date, that there is currently no reliable way to identify and amplify local voices in impact areas, or to ensure that their needs are met and warnings are received.

Overall, a 60% majority preferred shared public and official hashtags. These OLs cited the same benefits identified by both standalones, but focused on how each augmented the other's limitations. They posited formal hashtags were inflexible, too general, chiefly met emergency management needs, and rigidly forced users to play hashtag catch-up as events changed. They agreed official information is slower than public tweets and causes formal hashtags to not be utilized early enough. OLs also recognized lay users are greater in number, usually online earlier, geographically more dispersed than first responders, and a valuable resource for situational awareness. However, they also emphasized that formal feeds offer a leading edge in accuracy, and furthermore that last-mile audiences may purposefully subscribe to formal feeds to obtain notifications. These critical users are less likely to be looking for or to see public hashtags because they use Twitter less.

The general consensus was that different hashtags benefit different audiences at different times. Formal hashtags helped users know where to go to find or contribute information. Crowd participation in informal hashtags, namely through retweets, improved information volume, veracity, and variety. Formal hashtags provided alerts and official confirmations and validations as events unfolded. They were considered less effective for dissemination, but more effective for coordination and interoperability. In contrast, informal hashtags were seen as critical for broad, fast, and local engagement, adaption to changing situations, and directing users to formal conduits. Many OLs argued hashtag control is not possible, and because they evolve quickly users must accept the ones that dominate. Many also agreed appropriateness, popularity, and virality trumped point of origin. They implied that, to utilize hashtags well, emergency management must be online immediately, participate in both streams, and not attempt to control flow in favour of moving with hashtags fluidly as they evolved. As such, a hashtag's origin or purpose were less important than that it resonated with users, was indeed being used, and was shared heavily. Both formal and public methods were thought to improve communication in different ways that, together, provided the most robust range for response efforts compared to either method alone.

**Table 5.10 Respondent Stakeholder Group, Country, Community Type, Coastal Access, and In-Degree Hashtag Preferences**

| | Groups with the Highest Hashtag Preferences | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hashtag | 1st SG | %Col | 2nd SG | %Col | Country | %Col | Cmnty | %Col | Coastal | %Col | In-Deg. | %Col |
| **Formal** | Citizens | 38% | PubSec | 33% | **CAN** | **33%** | **Urban** | **29%** | **Yes** | **29%** | None | 3% |
| **Informal** | Other | 13% | T. Media | 10% | CAN | 8% | Urban | 8% | Yes | 8% | Strong | 8% |
| **Both** | PrivSec. | 78% | Govt. | 76% | **USA** | **71%** | **Rural** | **75%** | **No** | **63%** | **Strong** | **61%** |
| **Neither** | Hobbyist | 29% | PrivSec. | 11% | None | 3% | Urban | 3% | No | 7% | None | 27% |
| **Unsure** | Citizens | 16% | First Resp | 10% | None | 6% | None | 6% | Yes | 7% | **Weak** | **9%** |

Table 5.10 is a reduction of comparisons that shows the top two stakeholder groups and top country, community type, coastal access and in-degree category with the strongest preference for each hashtag type. Entries marked "None" indicate no difference between categories. Column percentages show the maximum portion of OLs with that preference. Notably, US OLs preferred shared hashtags whereas BC OLs favoured formal hashtags. Urban OLs preferred formal hashtags, while rural OLs preferred shared hashtags. Coastal OLs preferred formal hashtags while non-coastal OLs preferred both. Weak tie OLs were more unsure than strong tie OLs, whereas strong ties preferred both hashtag types more. For stakeholder groups, first response and lay OLs were the most unsure about hashtags. Public sector and lay OLs preferred formal hashtags most, while traditional media and other category OLs preferred informal hashtags most. Government and private sector OLs preferred shared hashtags most. Private sector and hobbyist OLs preferred no hashtags most. Overall, groups tied to emergency management, except the public sector, tended to be less unsure, less tied to formal hashtags, and far more interested in utilizing both. Although all groups preferred sharing hashtags most, it is interesting that BC OLs saw a much greater need for formal hashtags. Increased presence of groups interested in control, namely public sector and lay OLs, may explai this added reluctance.

Responses were less varied when it came to who OLs thought should control disaster information flow. The 16% who thought emergency managers should have control saw managing information, especially misinformation, as tantamount. Like the formal hashtag camp, these OLs thought content and flow control improved accuracy, trustworthiness, timeliness, and response accuracy. Some felt public control diluted communication efficacy, while others said the public had an important but limited support role as content amplifiers. In contrast, only 1% thought the public should have sole control, and only 3% thought neither party should attempt flow control. These OLs agreed information control was a flawed premise. They stated regulation impedes stakeholders on having enough information on hand to, as one user called it, "sift the wheat from the chaff themselves".

Overall, 80% thought emergency management and publics should share control. Again, this group recognized the pros and cons established by the solo camps and explained how each could mutually benefit the other. OLs recognized formal control was problematic because emergency managers were slower to respond and unable to be open with all information as fast as might be demanded because it takes time to verify. At the same time, they also noted public control increases scare time and confusion while information is validated, causes inundation, has a higher aggregation time because of its volume, and requires greater noise filtering to be useful. Formal control was considered integral for establishing leadership, dampening distortion, spamming, and misinformation, providing alerts and access to government sensory data, communicating the big picture, evaluating accuracy, centralizing, curating and directing information for target audiences, and accountability. At the same time, OLs agreed public content amplifies messaging, is faster, and has a wider reach. They noted that publics bring incidental findings like new events or changes to light. They can also disseminate information between different networks more easily, provide unfiltered ground truth of unfolding events, grant access to remote or rural communities where there may be no emergency management Twitter presence, and, critically, help jump start recovery earlier by increasing agency and empowering users to participate in the mitigation process.

Most of all, OLs stressed multi-way communication between emergency management, and other stakeholders, including the general public, and collaborative and cooperative trust relationships between them and OLs as critically important. They valued the public's ability to extend emergency management eyes and ears, which often suffer from lack of personnel or site access. By finding ways to trust and work with the public, OLs could radically boost their ability to coordinate response with other stakeholders, and freed up communication lines to reduce saturation. Situational awareness, not just for emergency managers but all users, was repeatedly emphasized. The potential for teamwork within and between SGs was considered a game-changer that only shared control could provide.

**Table 5.11 Respondent Stakeholder Group, Country, Community Type, Coastal Access, and In-Degree Hashtag Preferences**

| Group | 1st SG | %Col | 2nd SG | %Col | Country | %Col | Cmnty | %Col | Coastal | %Col | In-Deg. | %Col |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **EMGT** | Hobbyist | 29% | PrivSec | 22% | **CAN** | **22%** | **Urban** | **16%** | None | 15% | **Strong** | **18%** |
| **Public** | T. Media | 3% | S. Media | 3% | None | 1% | None | 1% | None | 1% | None | 1% |
| **Both** | Govt | 84% | Citizens | 82% | **USA** | **90%** | **Rural** | **88%** | None | 81% | **Weak** | **84%** |
| **Neither** | First Resp | 15% | Hobbyist | 15% | USA | 5% | Urban | 3% | None | 3% | None | 3% |

Although less pronounced than with hashtags, there were also stakeholder group, country, community type, coastal access, and in-degree differences in content control preferences that have implications for warning in BC (Table 5.11). Proportionately, BC OLs preferred formal control while US OLs preferred to share dissemination management with publics. Rural OLs preferred shared control, while urban OLs preferred emergency management or no control. Coastal access had no effect on preference. Weak ties were more interested in sharing and strong ties preferred information control. By stakeholder group, hobbyists, and private sector OLs preferred control while traditional and social media OLs were the only groups to support public control. Government and lay OLs preferred shared control most, and first responders and hobbyists preferred no control most. Overall, non-EM OLs preferred sharing more while EM groups preferred formal control slightly more.

**Table 5.12 Hashtag and Content Control by Country**

| Hashtag Preference | Content Control Preference | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | EMGT | | | Public | | | Both | | | None | | |
| | Country | n | %Col | Country | n | %Col | Country | n | %Col | Country | n | %Col |
| Formal | **CAN** | **7** | **39%** | None | 0 | 0% | CAN | 20 | 33% | None | 0 | 0% |
| Informal | CAN | 1 | 6% | None | 0 | 0% | CAN | 5 | 5% | None | 0 | 0% |
| Both | USA | 2 | 100% | CAN | 2 | 100% | **USA** | **26** | **68%** | USA | 2 | 7% |
| Neither | CAN | 1 | 6% | None | 0 | 0% | None | 1 | 1% | None | 0 | 0% |
| Unsure | CAN | 2 | 11% | None | 0 | 0% | None | 3 | 5% | None | 0 | 0% |

Interestingly, OLs who preferred information control were more also likely to prefer formal hashtags while OLs who preferred public, shared, or no control were more likely to prefer shared hashtags. Furthermore, when controlled by country, all OLs who preferred formal information and hashtag control were in BC (Table 5.12). Given that all user groups preferred shared hashtag and content control overall it is interesting that BC and urban users come up twice with stronger formal information management preferences than other groups. The data indicate a cultural difference exists between BC and US, and rural and urban Twitter communication practices and procedures. These, in turn, likely correspond to different forms of information diffusion in the CSN based on these allegiances. For example, it is reasonable to hypothesize from these results that more BC, and in particular BC urban users, will endeavor to use EMBC established hashtags to warn, and if they are not careful to incorporate public hashtags and contributions may end up excluding rural users from their information networks. It is also notable that almost of third of OLs who do not identify with a disaster management stakeholder group (citizens) prefer formal hashtags even though over two thirds prefer to share content contributions and control, suggesting publics in BC are expecting and will be seek out formal channels of information.

## 5.4. Boots on the Ground

Comparing stakeholder group, country, community type, coastal access, and in-degree data against OL reasons for following NTWC, warning source access, Twitter use, and perceptions of benefits and limitations helps shed light on how these variables impact warning capacity for BC. Table 5.13 shows that compared to the US, BC OLs followed @NWS_NTWC for more singular reasons and had slightly lower general and coastal hazard awareness. All rural OLs followed NTWC more for all or other reasons, and to disseminate to people they knew personally. Compared to urban users they were more coastal hazard aware, but found Twitter less useful for tsunami early warning. Coastal and non-coastal OLs followed NTWC equally for all reasons, except non-coastal OLs tracked notifications more. Lastly, compared to strong tie OLs, weak tie OLs followed NTWC to tweet public warnings less but for general interest or to track bulletins for local areas more.

**Table 5.13 SG, Country, Community Type, Coastal Access, and In-Degree Warning Reasons and Confidence**

| | @NWS_NTWC Follow Reasons | | | | | | OL Confidence | | |
|---|---|---|---|---|---|---|---|---|---|
| Group | All | Other | Collect | Personal | Public | Track | GenHaz | CoastHaz | Twitter |
| 1st Top SG | Other | Pub Sec | Priv Sec | Other | T. Media | Citizens | All Else | PubS/PriS/FR | T. Media |
| % Col | 75% | 7% | 22% | 13% | 26% | 40% | 100% | 100% | 90% |
| 2nd Top SG | Hobby | FirstResp | FR/Hob | Gov | S. Media | Priv Sec | Media/Gov | S.Media/Gov | Gov |
| % Col | 71% | 5% | 14% | 5% | 18% | 11% | 97%/94% | 97% | 81% |
| Last SG | Citizen | All/Gov | PubS/Oth | PrivSec/Hob | FirstResp | FR/Other | Citizen | Hobby | Hobby |
| % Col | 31% | 0%/3% | 0% | 0% | 10% | 0% | 88% | 86% | 71% |
| Country | USA | CAN | CAN | CAN | None | None | USA | USA | None |
| % Col | 56% | 5% | 10% | 5% | 16% | 19% | 98% | 98% | 80% |
| Community | Rural | Rural | Urban | Rural | Urban | None | None | Rural | Urban |
| % Col | 63% | 6% | 9% | 6% | 18% | 18% | 94% | 100% | 82% |
| Coastal | None | None | None | None | None | No | None | None | Yes |
| % Row | 49% | 3% | 7% | 4% | 15% | 22% | 94% | 93% | 81% |
| In-Degree | None | None | Weak | None | Strong | Weak | None | Strong | None |
| % Col | 50% | 3% | 11% | 4% | 23% | 22% | 94% | 97% | 80% |
| Total | 61 | 4 | 10 | 5 | 19 | 22 | 114 | 114 | 97 |
| % Row | 50% | 3% | 8% | 4% | 16% | 18% | 94% | 94% | 80% |

By stakeholder group, other category and hobbyist OLs followed NTWC for all reasons most while lay OLs did so least. Public sector and first response chose other reasons most with no other groups except government selecting this option. Private sector and first response picked tsunami information collection more, while public sector and other OLs did not select this option. Other and government OLs selected sharing to personal networks most, while first response did so least. Traditional and social media selected public dissemination most, and first response did so the least. Lastly, lay and private sector OLs tracked local alerts most while first response and other category users did so least.

For confidence readings, lay OLs reported being the least general hazard aware of all groups, while all other groups ranked in at 94% or higher. The same pattern occurs in coastal hazard awareness for hobbyists while all other groups reported 94% or higher. Traditional media and government were the most likely groups to see Twitter as useful for tsunami warning, while hobbyists ranked lowest.  It is as interesting to see groups unaffiliated with disaster mitigation track or plan to disseminate bulletins as it is relieving to see that groups with strong ties to disaster warning responsibility report high coastal and general hazard awareness and rank Twitter's role in disaster mitigation highly.

**Table 5.14 SG, Country, Community, Coastal & In-Degree Warning Sources**

| Group | Twitter | Email | WWW | SoMe | SMS | TMedia | Physical | Other | None |
|---|---|---|---|---|---|---|---|---|---|
| 1st Pref | T. Media | Public Sector | Priv Sec | Other | Public Sector | Other | Public Sector | Hobbyist | Citizens |
| % Col | 58% | 73% | 78% | 75% | 60% | 88% | 40% | 43% | 16% |
| 2nd Pref | Govt | FR / T.Media | Pub Sec | SMedia/Govt | Govt | T. Media | First Resp | Other | Govt |
| % Col | 57% | 71% | 67% | 71% | 57% | 81% | 29% | 38% | 3% |
| Last Pref | Priv Sec | Citizens | Citizens | Citizens | Citizens | Citizens | Hobbyist | Citizens | All Else |
| % Col | 33% | 16% | 34% | 41% | 16% | 56% | 0% | 3% | 0% |
| Country | CAN | CAN | USA | USA | USA | None | None | CAN | CAN |
| % Col | 54% | 66% | 61% | 59% | 43% | 70% | 27% | 15% | 6% |
| Community | Rural | Urban | Urban | Rural | Urban | None | Rural | Rural | Urban |
| % Col | 63% | 51% | 50% | 75% | 82% | 70% | 56% | 19% | 6% |
| Coastal | None | None | No | No | Yes | Yes | Yes | No | Yes |
| % Row | 52% | 51% | 56% | 59% | 38% | 71% | 30% | 14% | 7% |
| In-Degree | Strong | Strong | Strong | Weak | Strong | Strong | None | None | Weak |
| % Col | 62% | 67% | 53% | 53% | 41% | 77% | 27% | 14% | 7% |
| Total | 61 | 61 | 59 | 66 | 44 | 84 | 32 | 16 | 6 |
| % Col | 50% | 50% | 49% | 55% | 36% | 69% | 26% | 13% | 5% |

In terms of warning sources, BC OLs had more Twitter, email, and other sources, and less website, SMS, and other social media access than US OLs (Table 5.14). More OLs also had access to no other sources. All rural OLs had more Twitter and social media, physical, and other source access, and fewer OLs with no other sources than urban OLs. They also had less email, website and SMS access. Coastal OLs had more SMS, traditional media, and physical warning source access, as well as more OLs with no other source access than non-coastal OLs. Weak tie OLs had less Twitter, email, website, SMS, traditional media, and other source access, more social media access compared to strong tie OLs.

By stakeholder group, traditional media and government had the most access to other Twitter accounts while the private sector had the least. Public sector, first response, and traditional media had more email access. Private and public sector had more website access. Other category, social media, and government OLs had more access to other social media. Public sector and government had more SMS access. Traditional media and other OLs had more mass media access. Public sector and first response had more physical warning system access. It is notable that lay OLs had limited or least access to all sources except physical warning systems and Twitter. They were also the most likely to have no other sources available, followed by government. Whether OLs with no source access genuinely lack these media or simply awareness of their availability is unknown. Regardless, the data show Twitter to be especially vital for public access to warning media.

**Table 5.15 SG, Country, Community, Coastal, and In-Degree Usage**

| Group | 11+ hrs Use | Listen | DisTwt | 50% or more Twitter time Interact | DisInx | View | DisView |
|---|---|---|---|---|---|---|---|
| 1st Top SG | Govt | Priv Sec | Hobby | Citizen | Priv Sec | Other | Other |
| % Col | 73% | 78% | 29% | 39% | 56% | 88% | 63% |
| 2nd Top SG | First Resp | S Media | S Media | Other | Hobby | Citizen | Priv Sec |
| % Col | 71% | 76% | 26% | 38% | 43% | 84% | 56% |
| Last SG | Priv Sec | Hobby | Citizen | Priv Sec | Citizen | Govt | Citizen |
| % Col | 22% | 43% | 0% | 0% | 3% | 54% | 16% |
| Country | USA | USA | USA | CAN | USA | USA | USA |
| % Col | 55% | 73% | 28% | 35% | 43% | 80% | 45% |
| Community | Urban | Urban | Urban | Rural | Urban | Urban | Urban |
| % Col | 41% | 71% | 16% | 35% | 26% | 79% | 32% |
| Coastal | No | None | None | No | No | No | No |
| % Row | 41% | 69% | 14% | 44% | 37% | 82% | 41% |
| In-Degree | None | Weak | Strong | None | Strong | Weak | Strong |
| % Col | 39% | 72% | 19% | 34% | 33% | 84% | 34% |
| Total | 46 | 80 | 17 | 40 | 30 | 89 | 37 |
| % Col | 38% | 68% | 14% | 34% | 25% | 74% | 31% |

When it came to Twitter use, BC OLs were online, listened to NTWC, viewed, and tweeted, viewed, and interacted over disaster content less (Table 5.15). However, they did engage in general interactions more. Rural OLs expressed the exact same pattern compared to their urban counterparts. Non-coastal OLs surprisingly spent more time online, and more time interacting over and viewing both general and disaster specific content than coastal OLs. Weak tie OLs listened to NTWC and viewed general content more than strong tie OLs, but tweeted and interacted over disaster content less.

By stakeholder group, government and first response used Twitter most while private sector OLs did so least. However, private sector and social media spent more of their time listening to NTWC than other groups, and hobbyists did so least. On an average day, social media and hobbyists devote the most time to disaster tweeting while lay OLs devote the least. Hobbyist and social media tweet more disaster content, while lay OLs tweet the least. Lay and other OLs interact most, whereas private sector OLs do so least. However, private sector and hobbyists spent more interactions on disaster content while lay OLs did so least. Other and lay OLs also viewed more content, while government viewed the least. Other and private sector OLs viewed more disaster content while lay OLs viewed least.

**Table 5.16 SG, Country, Community, Coastal & In-Degree Non-Resp. Benefits**

| Group | Safety | Followers | Relation | PrevMitgn | Prepdns | HazRisk | RiskPop | Other |
|---|---|---|---|---|---|---|---|---|
| 1st Pref | Hobby | Other | Priv Sec | Pub Sec | Priv Sec | Other | Pub Sec | S Media |
| % Col | 100% | 75% | 78% | 87% | 89% | 100% | 53% | 8% |
| 2nd Pref | Priv Sec | T. Media | Pub Sec | First Resp | Other | Priv Sec | Hobby | TMedia/PubS |
| % Col | 100% | 68% | 73% | 86% | 88% | 89% | 43% | 7% |
| Last | Pub Sec | Citizens | Citizen | Citizen | Citizen | Citizen | Other | All Else |
| % Col | 87% | 41% | 41% | 59% | 72% | 66% | 25% | 0% |
| Country | CAN | CAN | USA | None | USA | USA | USA | None |
| % Col | 91% | 50% | 54% | 64% | 81% | 85% | 46% | 5% |
| Cmnty | Rural | Rural | Rural | None | Urban | Rural | None | None |
| % Col | 100% | 63% | 69% | 64% | 75% | 88% | 37% | 5% |
| Coastal | None | None | Yes | Yes | No | No | Yes | Yes |
| % Row | 90% | 48% | 52% | 67% | 82% | 82% | 38% | 5% |
| In- | Strong | Strong | Strong | Strong | Strong | Weak | Weak | Strong |
| % Col | 95% | 53% | 55% | 77% | 78% | 79% | 49% | 6% |
| Total | 109 | 59 | 62 | 78 | 90 | 91 | 44 | 5 |
| % Col | 90% | 49% | 51% | 65% | 74% | 75% | 36% | 4% |

For non-response and recovery benefits, BC OLs ranked preparedness communication, risk or hazard awareness, and at-risk population identification lower than US OLs, but ranked public safety information and increasing follower networks higher (Table 5.16). In all, rural OLs ranked Twitter as more beneficial than urban OLs, specifically for public safety, follower and relationship expansion, and hazard and risk awareness, although they ranked Twitter lower for preparedness use. Coastal OLs ranked relationship building, prevention and mitigation information, and at-risk population targeting outside of a disaster as more beneficial than non-coastal OLs, but ranked Twitter lower for preparedness communication and hazard and risk awareness. Weak tie OLs rated Twitter as less useful than strong tie OLs for all non-response benefits except hazard and risk awareness and identifying at-risk populations.

By stakeholder group, public safety information was rated as Twitter's best utility. Hobbyist and private sector OLs preferred it most, and other OLs did so least. Other and traditional media selected boosting followers most. Private and public sector OLs valued Twitter for developing follower relationships most. Public sector and first response preferred prevention and mitigation communication most. Private sector and other OLs selected preparedness communication most. Other and private sector OLs picked hazard and risk awareness social media most. Public sector and hobbyist OLs ranked identifying at-risk populations highest and other OLs ranked it least. Lastly, social, traditional media and public sector were the only groups to specify other non-response communication benefits. Lay OLs were the most skeptical about all benefit options except public safety information.

**Table 5.17 SG, Country, Community, Coastal & In-Degree Response Benefits**

| Group | EWS | MassS | LocalS | MonitorS | Coord | Intrp | SitAw | LstMle | RPrev | Fund | ScSup | Aid | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1st Pref | TMedia | All Else | PubSec | Other | Priv Sec | Other | Other | Other | Pub | Hobby | Hobby | Other | Govt |
| % Col | 100% | 100% | 87% | 88% | 67% | 63% | 88% | 63% | 87% | 57% | 57% | 63% | 14% |
| 2nd Pref | SMedia | Govt | T Media | SMed/Hob | Other | Gov | Gov | TMedia | Priv | Other | Other | Hob. | Hob. |
| % Col | 95% | 92% | 77% | 71% | 63% | 49% | 84% | 45% | 78% | 38% | 50% | 57% | 14% |
| LastPref | Govt | Citizen | Priv | Priv Sec | Citizen | Citizen | Priv | FR | Citizen | Priv | Priv | Priv | Pub |
| % Col | 84% | 78% | 56% | 56% | 28% | 28% | 67% | 24% | 66% | 11% | 11% | 22% | 0% |
| Country | CAN | USA | None | USA | None | USA | None | USA | CAN | USA | USA | CAN | None |
| % Col | 93% | 95% | 75% | 66% | 40% | 42% | 77% | 54% | 74% | 24% | 39% | 44% | 6% |
| Cmnty | Urban | Rural | Urban | None | Urban | None | Rural | Urban | Urban | Urban | Urban | Urban | None |
| % Col | 93% | 94% | 76% | 64% | 42% | 39% | 88% | 39% | 73% | 22% | 38% | 43% | 6% |
| Coastal | Yes | No | Yes | Yes | Yes | None | Yes | No | Yes | Yes | No | No | Yes |
| % Row | 93% | 96% | 80% | 65% | 43% | 40% | 77% | 48% | 73% | 22% | 37% | 44% | 7% |
| In-Deg. | None | Strong | Strong | None | None | None | None | Weak | Strong | None | Weak | Strong | None |
| % Col | 92% | 95% | 80% | 64% | 42% | 42% | 77% | 47% | 77% | 21% | 39% | 44% | 6% |
| Total | 111 | 111 | 90 | 77 | 49 | 48 | 93 | 46 | 88 | 25 | 42 | 51 | 7 |
| % Col | 92% | 92% | 74% | 64% | 41% | 39% | 77% | 38% | 73% | 21% | 35% | 42% | 6% |

During response and recovery, BC OLs ranked Twitter as more beneficial than the US for early warning, rumor prevention, and providing or receiving aid (Table 5.17). They ranked it lower for mass notification, monitoring, interoperability, fundraising, last-mile access and social support. All rural OLs rated Twitter less beneficial than urban OLs in all categories except monitoring and stakeholder coordination, which both groups ranked equally, and situational awareness, which was rated higher. Coastal OLs rated all benefits higher than non-coastal OLs except interoperability, which was rated equally, and mass notification, last mile population access, social support, and providing or receiving aid, which were lower. Weak tie OLs valued Twitter for last mile reach and social support more than strong tie OLs, and for rumor prevention, and providing or receiving aid less.

By stakeholder group, traditional and social media preferred Twitter as an early warning system most and government did so least. Everyone except government and lay OLs unanimously preferred Twitter for mass notification. Traditional media and public sector preferred local notifications most and private sector did so least. Other, hobbyist, and social media selected monitoring most, and private sector did so least. Private sector and other OLs preferred stakeholder coordination most and lay OLs did so least. Other and government OLs selected interoperability and situational awareness most, while lay OLs selected the former and private sector selected the latter least. Traditional media and other selected last-mile access most, and first responders did least. Public and private sector chose rumor prevention most as lay OLs did least. Hobbyist and other picked fundraising, social support, and finding or receiving aid most and the private sector did so least. Lastly, government and hobbyists cited other benefits most while the public sector did so least.

**Table 5.18 SG, Country, Community, Coastal, and In-Degree Limits**

| Group | Short | Reach | See | Cntrbte | Authty | Exploit | Misinfo | Control | Other | None |
|---|---|---|---|---|---|---|---|---|---|---|
| 1st Concern | T. Media | T. Media | T. Media | Pub Sec | Other | Hobbyist | Other | Priv Sec | Other | Hobby |
| % Col | 48% | 77% | 7% | 20% | 63% | 43% | 88% | 56% | 25% | 14% |
| 2nd Concern | Pub Sec | Citizen | S. Media | Gov | FirstResp | Other/Citzn | Pub Sec | Other | Govt | Other |
| % Col | 40% | 69% | 3% | 19% | 62% | 25% | 73% | 50% | 16% | 13% |
| LastConcern | Hobbyist | Priv Sec | All Else | First Resp | Citizens | Govt | FR/Hobby | Citizen | Citizen | PubS |
| % Col | 14% | 44% | 0% | 9% | 34% | 16% | 57% | 24% | 0% | 0% |
| Country | CAN | USA | None | CAN | CAN | CAN | None | CAN | CAN | None |
| % Col | 29% | 73% | 2% | 15% | 53% | 26% | 68% | 35% | 13% | 5% |
| Community | Urban | None | None | Rural | Rural | Rural | Rural | Rural | None | Urban |
| % Col | 85% | 70% | 1% | 31% | 63% | 31% | 88% | 38% | 12% | 5% |
| Coastal | None | No | No | No | Yes | None | None | No | None | None |
| % Row | 27% | 78% | 7% | 15% | 48% | 23% | 67% | 41% | 11% | 4% |
| In-Degree | Weak | Strong | None | Strong | Strong | None | Strong | Strong | Strong | None |
| % Col | 32% | 72% | 2% | 19% | 52% | 23% | 70% | 34% | 14% | 4% |
| Total | 33 | 85 | 2 | 16 | 55 | 27 | 83 | 38 | 13 | 5 |
| % Col | 27% | 70% | 2% | 13% | 46% | 22% | 69% | 31% | 11% | 4% |

Lastly, for Twitter's limitations, BC OLs ranked short message length, the ability for anyone to contribute to tweets, lack of authority, tweet exploitation, inability to control tweets, and other concerns higher than US OLs (Table 5.18). The only category ranked lower was inability to reach target audiences. All rural OLs also were more concerned about Twitter than urban OLs, specifically that anyone could contribute, lack of authority, exploitation and misinformation potential, and lack of control. They were more likely to disagree that Twitter had no limitations as well. The only category they rated lower was message length. Coastal OLs were more concerned about lack of authority than non-coastal users, but less concerned about audience reach, that anyone can see or contribute to messages, or lack of control. Weak tie OLs had lower public contribution, control, lack of authority, control, and other limitation concerns, equal concerns about exploitation and anyone seeing, and higher message length concerns compared to strong tie OLs.

By stakeholder group, traditional media and public sector were most concerned that messages were too short while hobbyists were the least. Traditional media and citizens were most concerned about messages would not reach intended audiences, and private sector OLs were the least. Traditional and social media were the only groups to be concerned that anyone could see messages. Public sector and government were the most concerned about anyone being able to contribute to messages while first response was the least. Other and first response OLs were most concerned about authority loss while lay OLs were the least. Hobbyist, other, and citizen OLs were the most concerned about exploitation while government was the least. Other and public sector were most concerned about misinformation while first response and hobbyist were the least. Private sector and other OLs were most concerned about lack of control while lay OLs were least. Other and government OLs were most concerned about other limitations while lay OLs were the least. Lastly, hobbyist and other OLs were the most likely to think Twitter had no limitation while public sector was most likely to disagree.

**Table 5.19 Stakeholder Use and Opinion Matrix**

| | | Use Pattern | |
|---|---|---|---|
| | Interactivity | Active | Passive |
| Interaction | Engaged | Social media | Public sector, other, none |
| | Removed | Traditional media, first response, government | Hobbyist, technologist, private sector |
| Confidence | Confident | Traditional media, social media, | public sector, private sector ,other, |
| | Cautious | first response, government, | Hobbyist, technologist, none |
| Outside Disaster Benefits | Skeptical | Traditional media, Social media, government, first response, | hobbyist, private sector, |
| | Supportive | | public sector, technologist, other, none |
| Response & Recovery Benefits | Skeptical | | private sector, other, none |
| | Supportive | traditional media, government, Social media, first response, | public sector, hobbyist, technologist, other |
| Limitations | Concerned | Traditional media, government, | public sector, technologist, other |
| | Relaxed | Social media, first response, | hobbyist, private sector, none |

Overall, stakeholders have clear response patterns (Table 5.19). Traditional media are confident about their awareness and influence, removed, in that they are not interactive despite being heavy tweeters, and skeptical about Twitter's benefits. Social media OLs are confident, active in that they are online and tweeting, engaged in that they spend time interacting, and mostly supportive of Twitter's benefits over its limitations. Public sector and lay OLs are cautious in that they tend not to rate Twitter or their influence as highly as other groups, passive, in that they don't tweet as much as other groups, but also engaged and supportive. First responders are cautious, active, removed, and supportive. Government OLs are cautious, active but removed, and skeptical. Technologists and hobbyists are cautious, passive, removed, and supportive. Private sector OLs are confident, passive, removed, and skeptical. Other OLs are confident, passive, engaged, and supportive. Cumulatively, social media, public sector, and other OLs are *engagers* where traditional media, government, technologist, private sector, hobbyist, and lay OLs are *listeners,* preferring to broadcast, listen, or view over direct interaction with other users. It is notable that BC OLs have more first response, more government, and more lay stakeholders than the US, as all three groups fall solidly into the *listeners* camp.

## 5.5. The Way Ahead

Overall, the survey data indicate that closer to tsunami risk, and the more ties to the CSN, the less confident OLs are in Twitter's ability to reach last miles or coordinate response. BC OLs in particular are doubtful. In all, BC's 79 OLs made up 66% of the 121 survey responses. Moreover, 81% (10 of 13) of rural OLs were in BC, as were 75% (69 of 72) of coastal OLs, and 58% (33 of 58) of weak tie OLs. Only 33% of weak tie OLs considered themselves influential, and it is likely that these are rural or non-coastal OLs in the private sector or lay stakeholder groups. Furthermore, because of majority membership, findings for rural and coastal OLs can be applied to warning communication in BC and to the CSN data to qualify structural differences in warning between various BC groups.

Specifically, BC OLs are less confident in Twitter for tsunami warning and in their own general and coastal hazard awareness. They are less likely to rate themselves influential (especially weak tie OLs), are online on Twitter less, and participate in creating or sharing of disaster content less, although they are more interactive than US OLs in general. BC OLs also report having fewer and less diverse warning source access, and on older ICTs such as email more. They are less likely to rate non-response benefits highly, and when they do they prefer tactics associated with broadcasting over collaboration much more than US OLs, especially in regards to spreading public safety information and building follower networks. Presumably the intent here is to expand message reach rather than foster community since these OLs preferred to build networks over relationships.

During response and recovery, BC OLs preferred methods associated with broadcasting or monitoring, rating notification and situational awareness benefits highly, as well as rumor prevention, again suggesting an interest in crowd control over engagement. It is also interesting that BC OLs ranked providing or soliciting aid higher than the US without also ranking coordination, interoperability, or last mile access highly, suggesting they view Twitter as a way to identify areas in need from a birds' eye view and managerial approach. Finally, BC OLs were more likely to see Twitter as a limitation than the US, and particularly in areas pertaining to authority and public participation control. While BC OLs were also not in favour of Twitter's message length, this is a technical limitation that speaks to difficulty fitting the medium into their current communication practices and requirements, whereas other items, such as lack of authority, are more likely to be socially derived from incompatibility with current emergency management practices and policies. When these data are coupled with their greater preference for hashtag standardization and information control, BC OLs are more in favour of treating Twitter as a megaphone broadcast system that replicates and amplifies the hierarchical dissemination of mass media communication rather than as a collaborative network that relies on the participation of publics not only to create and share information, but to manage and act on that information as well.

Rural, coastal, and weak tie responses support this argument. Rural OLs are staunch non-response communication supporters but they, too, have higher information authority and control concerns despite considering themselves more influential, more confident in Twitter, and more willing to share hashtag and content control. Moreover, because coastal OLs spend less time on Twitter, the fact that they spend equal or more time involved in disaster content as non-coastal OLs suggests greater interest relative to availability, and a tendency to engage Twitter strategically rather than for day to day communication needs. Both subsets replicate the image of BC OLs as detached broadcasters as opposed to participatory network liaisons. Finally, given that fewer weak tie OLs work in disaster management, their tendency to avoid strong opinions about Twitter or to participate in disaster content distribution suggests they are more interested in seeking information than in disseminating it, particularly in BC where influential weak tie OLs are scarce and occupy stakeholder groups outside traditional disaster mitigation.

Ergo, even though BC's rural coastal OLs have more formal connections to emergency management and greater willingness to participate, their capacity to warn is limited by their reduced Twitter access and use, and by their tendency not to use the site collaboratively with other stakeholders. In contrast, given non-coastal OLs are distant from tsunami risk, have increased urban userbases, Twitter usage, US membership, and tendencies to follow NTWC to track alerts, rate benefits lower and limitations higher, be influential weak ties, and be first responders suggests that the majority of this group has formal ties to emergency management in Twitter that would allow them to relay NTWC messages into BC as well as out of the CSN, although at this time those destinations are unknown. Having access to influential weak tie OLs in the US is important, but it does not help much in the way of getting BC OLs to propagate dissemination themselves.

Overall, this lack of confidence is sensible given BC's greater number of rural, remote, isolated, or transient populations without social media access. However, when their elevated concerns about authority and tweet control are considered in conjunction with their higher preference for hashtag and content control, greater proportion of *boosters* and *coordinator* stakeholder, and increased *listening* stakeholder group behavior, an emergent hands-off approach to managing and curating information appears that US opinion leaders do not appear to share. Since they report access to more and greater non-traditional warning sources, perhaps US OLs utilize more mobile applications, social media included, for emergencies and are more comfortable doing so. Early adopters and the subsequent surge in public information officers responsible for engaging Twitter networks continuously as a part of mitigation policy in the US may also explain this discrepancy (e.g. Latonero & Shklovski, 2011). So would FEMA's extensive support and funding of social media response initiatives in the US, an initiative that EMBC is only just beginning to replicate. Given that most rural users are in BC and also more likely to live in vulnerable tsunami warning zones, this skepticism is healthy. These OLs will likely experience information dearth during a disaster. As such, their preference for using Twitter for broadcasting and to obtain data rather than for stakeholder collaboration makes sense even if doing so is against best practices for communication spread and behavior influence that stipulate emergency management must take a more integrative and collaborative approach.

# Chapter 6. Analysis: Emerging Solutions

Arriving on the far side of a detailed exploration of the CSN's network composition and its opinion leader's opinions and usage behaviors, it is clear the implications both datasets hold for tsunami early warning in British Columbia are intertwined and multi-faceted. The communication lines between followers vary dramatically and traverse across stakeholder group, country, community, and coastal risk geography. The communication practices of influential opinion leaders undoubtedly influences how these lines are used and whether or not warning messages circulate within the CSN and in networks beyond. This analysis chapter brings the core network and survey findings together to answer the study's core research question of how the CSN can best support tsunami warning in British Columbia. It starts by discussing what OL's feel could be improved about Twitter that would make the process of early warning easier for them, which of course would translate to differences in CSN structure over time as users change their engagement with the platform. It then discusses the current network and survey findings within the context of the best practices outlined in the thesis' literature review to assess how well these are met, where they are not being met, and to make recommendations about what should be done next to address any gaps. The major finding that falls from this assessment, and that has been alluded to throughout this work, is that the CSN is not positioned to warn on a network scale, and BC stakeholders and opinion leaders are particularly isolated from each other. Following this assessment, the role of the CSN can be applied as a warning medium in BC is discussed, and, lastly, the CSN network findings are reviewed to determine what steps can be taken to make warning in BC more effective and robust.

## 6.1. Recommendations for Improvement

Among their many contributions, opinion leaders suggested a range of solutions to issues raised in regards to early warning and disaster communication. Most focused on improving timeliness, accuracy, quality, and localization. For instance, many called for greater public education and advertising on how to use Twitter during emergencies, especially which accounts to follow or hashtags to use. Some also pointed to third-party tools. For instance, adopting TweetChat to manage conversations was suggested as a way to increase trust and engagement by increasing emergency management presence, availability, and response time. Content management systems that provided an all-points push to multiple media outlets simultaneously were also highly recommended. Another suggestion was to teach publics to leverage Twitter features like SMS or direct messaging to reduce network load. Others expressed a need for strategies that continuously manage user expectations, increase disaster content, circulation, and clarity, and utilize lay language. These should be accessible and standardized, establish consistency, and accommodate differently abled users, such as the blind or non-English speakers. Lastly, OLs acutely stressed that finer detail and location data would improve Twitter's value to them substantially.

Furthermore, OLs expressed the need to dispel assumptions that Twitter is for expressing daily life banalities, and to increase public interest, participation, and engagement with Twitter and emergency management. To this end, OLs wanted increased emergency management timeliness, immediate support ability, 24/7 presence, strategies for fact confirmation, and dedicated communication staff for managing information. This role included debunking misinformation, locating information seekers, relationship building and management, and granting transparency into emergency management practices and processes. Collaboration between state and local authorities, identifying locals during an event, and especially in getting locals engaged in early detection and reporting were seen as critical. The need for increased preparedness tweeting, and community trust in ground truth and public information were also stressed. Developing and advertising lists of local accounts improving disaster management's relationship with traditional media and to ensure verified accounts, hashtags, and instructions are publicized was also suggested.

Operationally, OLs thought Twitter could be integrated better into local, state, and national emergency management programs. Assets such as early stakeholder detection could help establish agreements about roles, responsibilities, and ways to best assist mitigation in advance. Some desired greater differentiation for designated accounts to meet different disaster communication needs, such as alert, response coordination, and general information accounts, and to restrict off-topic tweeting in each. A frequently cited idea was to post update scheduling until risk abated so that all users could know when to expect new posts and not be left waiting indeterminately. Transmedia strategies that utilized all media outlets, including physical systems, as well as official accounts and hashtags that bridged social media platforms, including Facebook and Instagram, were emphasized in order to expand redundancy and audience reach. Users also argued for more embedded images, infographics, maps, other visual aids, and syntactical solutions that would limit links to outside information sources and by extension increase sharing and information clarity. Others pointed to the basic need for better Internet, cellular, and wireless coverage and infrastructure, especially in rural at-risk areas. Canadian OLs in particular requested that Twitter recognize formal emergency management accounts outside of the US, such as @emergencyinfobc, because recognized accounts are granted greater administrative leeway during times of crisis to prevent them from over posting. Greater access to risk metrics, location information, network data, and visualizations were also emphasized.

Finally, in the hashtag and information control section of the survey, many OLs hit home on the conflict between the need to be precise and targeted and the need to generate public participation and engagement. The two are not necessarily mutually exclusive but the catch-22 is that if a hashtag is too targeted, or information is too regulated, it will not be seen or shared, but if it is too open, and too widespread, the narrative may be too large, causing misinformation to spread faster and local voices to be silenced. Some suggestions hit on a possible answer: stop applying blanket solutions to meet formal and informal requirements. Instead, emergency management should leverage individual user strengths to build independent solutions depending on hashtag purposes, such as general information and specific purpose hashtags propagated and managed by publics and emergency management collaboratively. To this end, OLs emphasized the need to partner with Twitter to set up a location based emergency system. Features would include dedicated emergency response spaces in Twitter that made emergency accounts, event hashtags, and their purposes immediately visible. Ways to do so could include specialized notification colours or sounds to differentiate alerts from regular tweets on mobile devices, priority newsfeed placements based on location that could not be pushed down, and the ability to push messages to all Twitter accounts in a specified area regardless of whether they follow the source account or not. OLs also thought using tweets to trigger automated systems, and vice versa, would help push novel information to outside outlets faster. These improvements would make searching for emergency management accounts and hashtags easier, make alerts more noticeable, and increase stakeholder involvement.

## 6.2. Capacity Outcomes

With the importance of using big data analytics for decision making, and developing online communities for participatory sharing established, it is possible to answer the complicated question of how Twitter can best assist tsunami warning in BC. One way is to cross-check the study findings against the best practices established in the literature to see how well those standards are being met. From there it is possible to make a claim about how well the CSN is capable of warning remote rural communities, and from there make some generalizations about how Twitter best applies to tsunami warning in British Columbia.

*First responders should be online the moment an event occurs* (Potts et. al, 2011). The CSN is configured to meet this requirement, but only partially. According to the survey responses, first responders and government OLs use Twitter most. However, emergency responders spent more time on viewing content than on communication. Instead, it is social media, private sector, hobbyist, other category, and lay OLs who not only spend the most time tweeting and interacting with others, but over disaster content specifically. Compared to the US, BC users are online, listening to NTWC, and tweeting, interacting over, and viewing disaster content less. Rural and coastal users are similar. Thus, the CSN is not well positioned to warn in BC compared to the US, and especially not in rural areas, because disaster management are less active and because participating stakeholder groups, especially private sector and lay OLs, are not tightly integrated. To be fully effective, smaller groups like first responders will need to grow their followings and information sources ahead of time to establish an authoritative presence during an event. In particular, they need to connect with non-emergency management stakeholders more.

*Emergency management should develop proactive communities in advance* (Latonero & Shlovski, 2011; Starbird & Stamberger, 2010). Only half of OLs found Twitter valuable for growing follower numbers or relationships. Those that did are divided on the topic, with BC OLs more in favour of numbers over relationships. Rural OLs rated both benefits much higher than urban OLs, showing smaller communities value participatory and networked communication highly. Traditional media and other category OLs were most in favour of developing follower networks and private and public sector OLs were most in favour of developing relationships. So, even though BC OLs saw developing follower relationships as less beneficial, rural users and public and private sector stakeholders at least thought otherwise. For network development to be effective, buy in from other groups is needed. In particular, citizens, who did not see much benefit in developing relationships and do not spend time disseminating disaster information could be untapped allies because they are highly active on Twitter. As well, social media, hobbyist, and other OLs tweet actively, and private sector and lay users are highly interactive. Developing relationships with these groups could promote voices in disaster communication who are generally less active on Twitter, such as government or first response OLs. By encouraging buy in from all groups, the concept of a mutually developed network could flourish, but at this stage, follower network development is not being prioritized by BC OLs with a relationship emphasis.

*Emergency management should utilize a mix of formal and organic hashtags, and be willing to establish dominant hashtags in advance or to appropriate popular ones* (Potts et, al, 2011). In general, most opinion leaders were in favour of both establishing official hashtags and opportunistically coopting hashtags organically developed in response to events. However, there is a stronger trend of conservativism in favour of standardization in over a quarter of opinion leaders that is especially pronounced in BC and urban groups. Again, rural users are exemplary in their interest and willingness to share and develop collaborative solutions. Given how many OLs felt standardization was essential for information access and curating, it would seem the CSN still needs to be convinced of the public's ability to contribute to these tasks. What is clear is that to maximize the platform's benefits and reduce its limitations during warning, some BC OLs will need to relax hashtag control attitudes and spend more time pre-emptively engaging their follower networks to help them prepare for warnings.

*Emergency management should utilize Twitter communities to help clear misinformation* (Bruns et. al, 2012; Hughes & Palen, 2009; Sutton, 2010; Mendoza et. al, 2010; Spiro et. al, 2012). Opinion leaders agreed publics and officials should have a say in curating and disseminating information in Twitter. Multiway communication was heavily emphasized for its benefits to warning reach, speed, and accuracy. However, a larger minority of BC OLs felt that information control should remain squarely in the hands of emergency managers.

Very few OLs raised the idea of public misinformation management, although a handful alluded to it by recommending verified accounts to manage information expectations or openly trusting Twitter users to self-govern and regulate information. Most OLs saw Twitter as a tool for rumor and misinformation management, particularly in BC. At the same time, many, especially rural OLs, felt Twitter was problematic for creating misinformation in the first place. Private and public sector, first response, government, and social media OLs were more in favour of Twitter as a rumor prevention medium and, with the exception of the public sector, less likely to see Twitter as problematic for misinformation. Thus, the CSN and particularly its progressive media or emergency response users are more than willing to receive the public's help in misinformation management. However, it is difficult to say how much of a hand they feel publics should have in that process, although the inclination based on other responses from BC OLs is that greater EM control is preferred.

*Emergency management should support mass retweeting for general awareness and event capturing* (Starbird & Palen, 2010; Starbird et. al, 2012; Sutton et. al, 2014). Many opinion leaders mentioned the value of retweets for message visibility and speed. During response, opinion leaders almost unanimously supported using Twitter as a mass public notification system. This is one area in which the CSN is mostly united. However, given the network's low density outside of isolated communities or groups, especially in BC, this opinion is somewhat misaligned with the network's actual ability to disseminate. If content reaches a large enough trend status, visibility is obviously less of a concern, but for content that is more specific in nature the CSN's current composition would make it difficult for users to find one another's tweets at scale, despite their best intentions to do otherwise.

*Emergency management should also seek out and individually connect with locals on the ground* (Starbird et. al, 2012; Sutton et. al, 2014). OLs in emergency management were the least convinced Twitter could reach local and last mile populations. Traditional media, first response, government, and even the public sector are more comfortable using Twitter outside response, namely for public safety communication that is still akin to broadcasting rather than to the fluid, interactive but harder to manage environments that disasters create. OLs were divided on using Twitter to coordinate with locals and for stakeholder groups to interoperate. This deference is more pronounced in BC. One reason might be that California, Oregon, and Washington have larger populations and better coverage than

BC and Alaska, which may mean more last mile populations in the US are easier to access. This hesitance may also reflect difficulties in finding local contacts as a result of limited time and resources. Many OLs suggested better geolocation for notifications and content detection could help. However, at this time it seems this best practice is recognized and theory and hard for the CSN to deliver in practice. The network data, which shows citizen users are isolated information seekers, reinforces this conclusion.

*Emergency management should seek to provide authority, rapid updates, and schedules to manage flow over time and communicate all aspects of a warning without compromising public participation (Sutton et. al, 2014).* About two thirds of OLs agreed Twitter could be used as a local notification system and could provide situational awareness for unfolding events, but almost half of OLs, most of whom were rural, coastal, or in BC, were concerned about their lack of authority on Twitter as well, suggesting OLs may find it difficult to meet this expectation in online environments where information is uncontrolled. The CSN, at least internally, is not structured to fit this requirement. Lay users are not well followed by the CSN's other groups, especially not those typically affiliated with disaster management. That said, it is unclear what other populations CSN users have access to, so this point cannot be generalized outside the network. Still, many opinion leaders stressed the difficulties of managing information in a public space like Twitter, with some deploying third party tools like HootSuite to assist. These findings suggest OLs accept authority and tweet strategies are important, and are aware of the need to provide rapid, authoritative updates, but seem uncertain as to how to fill it as emergency information demands are complex. One solution might be to have trusted lay users share the load of these procedures.

At this point in time, the research is in agreement with Sutton and colleague's (2014) assessment that Twitter is a better supplement than replacement for early warning systems in BC. Twitter and the CSN bring a number of benefits to early warning in BC by providing insight on vested stakeholders relative to risk and how they can communicate. Big data analytics on CSN data could help early event detection, warning trajectory, and response success assessments. Citizen sensors within the CSN can provide situational awareness by providing live updates of events, and also assist in emergency management practices such as update scheduling and flow management if they are brought into the fold and provided instructions on how to do so. The CSN and other networks can amplify and circulate general interest content, while first responders can locate and coordinate with people on the ground more easily by having follower network data for other stakeholders besides just themselves to work off of. Big data analytics can aid in searching for local users by keyword or tweet patterns, but the best method is to know who those users are in advance and to establish a trust relationship with them ahead of time to ascertain their authenticity and assistance, which requires developing relationships in the CSN beyond what BC has currently invested.

## 6.3. Community Expansion

Membership in an online social network is valuable, but is not necessary to benefit from the speed, volume, and reach of networked communication. Twitter's chief contributions to disaster mitigation are that it negates communication hierarchies by providing information access horizontally across social strata, and increases lay agency in the production, sharing, and response to that information by enabling a cheap and efficient means to coordinate and collaborate with both expert and civilian stakeholders. There are numerous anecdotal cases that stretch the definition of networks to include transmedia or communication outside a site. For instance, after the 2010 Haiti earthquake a Facebook post about a local, Jean-Olivier Neptune, who was trapped beneath rubble, was seen by a friend in Montreal. She telephoned emergency responders in Port-au-Prince, who rescued the survivor in a matter of hours (CBC News, 2010). Jean-Olivier's story is just one in a rising tide that suggests social media can reach government agencies in times of crisis to improve mitigation efforts, even for those who are offline. Obviously, transmedia ability has important ramifications for BC when so many populations are off the grid.

Twitter's ability to connect users and communication systems outside a network's given range has direct consequences for BC within three kinds of scenarios. First, there are likely other Twitter users in at-risk rural locations in BC who are not connected to the CSN, who may or may not know others who are. Second, while rural users only make up about 15% of the CSN, they are present, they are interested in participating in and sensitive to disaster and warning communication, and they see their role within online communities as influential and important. Third, there are many people in rural or remote communities who do not have access to or do not use Twitter, who may or may not know someone who does. In all cases, BC's rural users are critically important points of contact for underserved communities, both online and off. Similarly, the OLs, and particularly BC's weak tie OLs, who are predominately in the private sector, may have connections to rural areas that are not directly connected to the CSN. The presence of rural and weak tie OLs is small but essential, and leads to two main recommendations for involving them further in the CSN as citizen sensors and warning agents.

First, EMBC should develop strategies to increase Twitter adoption and CSN membership in remote, isolated, or rural communities, prioritizing those that are in high risk areas and are underserved, or lack robust ICT and warning infrastructure. This approach would require developing public awareness campaigns and transmedia strategies that leverage print, electronic, and other social media platforms, preferably with a shared hashtag that identifies relevant conversations and community members. The focal point for this effort would be to draw attention to Twitter and the CSN not only as an information source, but as a communication system sorely lacking in membership in vulnerable areas.

To this end, a paradigmatic or cultural shift in how BC opinion leaders, and particularly those in rural locales, use Twitter to communicate is drastically needed. Specifically, more BC OLs need to relinquish their emphasis on broadcasting for public awareness to foster relationship development and informal communication with follower networks as a means of building trust, responsiveness, and community involvement. This means full time Twitter support in emergency response agencies, and it means responding to and participating in discussion, not relying on static information that is URL rich to get messages across. Here, a great deal can be learned from public information officers in the US who have built a foundation of early hazard alerting, public response, and information management through informal relationships on Twitter (Latonero & Shklovski, 2011). Likely this approach would require accounts specifically for alerting, like @NWS_NTWC, with individual users or agencies filling in the role as information coordinators and sources of immediate official information. Above all, EMBC and the agencies and people who participate in emergency management in BC must have systems that allow them to be online immediately, know how to alert specific users in their network in addition to general broadcasting, and become capable of providing and managing updates within Twitter. Their followers must be encouraged to use similar strategies with them and their own networks in turn. This kind of strategy, built on knowledge of communities and community participation, will help prevent local voices from being obscured because they will be known in advance. It will also help ensure a faster response driven from a culture of participatory communication.

Second, once BC's CSN develops a rural and participative user base, it would be prudent to develop behavioral strategies, in addition to technological ones, to initiate warnings through tertiary ICTs. In particular, volunteer programs with at-risk communities that coach CSN followers in BC on how to communicate a warning to locals and first responders in their areas in Twitter would go a long way towards addressing the lack of visibility users have into other stakeholders for an emergency. These programs should provide volunteers access to email, telephone, SMS or other distribution lists that they can contact during an emergency to notify local authorities, first responders, and people they may personally have contact with in impact areas, much as Jean Olivier's friend did to notify first responders in Haiti all the way from Montreal. This kind of program would not necessarily have to be resource intensive if run through social media, and indeed would help take the onus of round the clock support off of first responders by involving other users, including lay users, in community preparedness alerting plans that include Twitter. These kinds of programs should be run in conjunction with developing APIs in partnership with Twitter that can automate warning within a social network by location, and can also trigger outside systems programmatically or socially through the intervention of invested opinion leaders like the kind surveyed here in the Cascadia Subnetwork. Lastly, volunteer driven response, multi-stakeholder programs that are transmedia and involve multiple ICTs can be tested to assess the efficacy of users as citizen sensors who can trigger other warning systems via email, SMS, or telephone to local organizations and community members. These transformations would radically elevate Twitter out of its supplementary, backchannel status into a critical component in social warning for tsunamis and other disasters. To do so, Twitter and other social media must be recognized and championed as a critical public service on par with telephony or the Internet.

## 6.4. Network Operations

Lastly, recommendations can be driven from CSN findings to improve warning capacity for BC. Foremost, CSN users should work on improving their network density by following other NTWC followers in the PNC. In particular emergency management in BC should look into creating more mutual ties with citizens, academics, hobbyists, and the public sector, as these groups are much more on the peripheries of the network than are media or government. Government should spend time developing more mutual ties to improve their broadcasting role by increasing their information sources and audiences using a collaborative strategy to foster strong internal communication between themselves and others, especially citizens, first responders, and the public sector, since ties to media are already well established. Government should also endeavor to find more followers in academic or hobbyist fields, as these ties are lacking considerably for their group.

Media would also do well to develop more mutual ties with all groups to ensure information from all sectors can be obtained and passed on. First responders, and especially rural ones, and the public sector need to work on building mutual ties to other groups besides each other. Government and media need to be much more tightly integrated with these groups, as do citizens and the private sector, because first responders are the front lines of response for communities. Citizens and professionals with mutual interest in tsunami warning may want to consider following others in their stakeholder groups as well to enhance internal transfer. The private sector needs to spend more time gathering followers so that they can provide critical updates for businesses and communities for their area to groups that can assist, including government and the public sector. Academics and hobbyists, in addition to increasing their numbers, should continue their important role as bridges by seeking to increase the density of ties to groups that are not typically well connected, such as between citizens and the public sector. Finally, since OLs have identified a need to know media contacts in advance and to work with them to coordinate public communication, government and media users should use CSN data to seek one another out and develop and maintain network data to help them identify each other during times of need, as well as develop strategies for testing collaboration outside of those moments. This strategy can be led by emergency management and applied strategically to enhance connectivity within and between all stakeholder groups as part of a volunteer Twitter response program that identifies stakeholders relative to risk or information needs.

Second, BC users should increase ties within the province. Although US ties boost dissemination, connections within BC, while more reciprocal, are too localized and limited to very small groups. Consequently, they have a shorter range for sharing information. The data show information transfer from the US is valuable for getting warning information across the border and for helping to connect stakeholder groups, but it would behove BC users to increase access to local areas as well. Third, the CSN across the board needs to develop ties with local users in at-risk rural locations as a foundational rule of operation. The survey and network data indicate, clearly, that rural users are present and invested in the CSN as a warning medium, but they do not see the benefits or limitations of Twitter as easily as emergency management do and are not as integrated with the network as many other groups. Furthermore, any rural community in BC that has access to cellular, wireless or Internet infrastructure could benefit from having local involvement in the CSN. Seeking these communities out either through an open call to participation, or by using location metadata, network analysis, or profile content analysis to find them may help identify users in at-risk areas who may be interested in participating in the CSN.

Strategies for increasing connectivity between stakeholder groups and communities could be as simple as regularly scanning @NWS_NTWC and @emergencyinfobc's followers for users located in target areas or groups, following them, and proactively working to develop relationships with them for the purpose of communication to mitigate disasters. To go a step further, emergency managers could encourage other stakeholders to consider themselves as citizen sensors is an online warning system, and regularly publish network data that indicates to members what state the CSN's warning capacity currently resides in and what areas need improvement, allowing users to make connections themselves locally to strengthen the network in ways that are personally meaningful, as numbers must never stand as a proxy for people or their needs. Most of all, emergency management could adopt similar big data strategies to model and assess the health of their warning networks so that they can keep a continuous process of observation available that will keep them informed on where messages can and cannot reach based on follower ties. A similar network for #NTWC hashtag use would complement these data nicely.

In this way, network analysis of pre-event warning communities benefits response and recovery efforts in a way post-event studies cannot. They identify the current volume, location, and interconnectivity of tsunami warning stakeholders, highlight opinion leaders and users with access to at-risk locations, and confirm which users do not have access relative to location data provided. They also can say with reasonable certainty which groups are the most invested in the network, thus helping to develop connections with users in advance to make communication throughout the CSN more robust. If gathered longitudinally, big data analytics could help in developing audience and location specific strategies for improving public awareness, engagement, and participation in disaster mitigation activities. Repeat measurements can also help to build foundational data that can be compared to response, recovery communication during actual events in order to see how well pre-event networks can predict communication patterns.

As well, such studies could help establish the validity of social network metrics in studying network performance and providing it real-world applicability by continuously pairing network and ethnographic data in order to align observations to the lived experiences of using Twitter for disaster warning. In a similar vein, metrics that identify different communicative strengths and weaknesses in stakeholder groups can help members of those groups develop cultures and practices that leverage their abilities and improve on their weaknesses. For instance, first responders who are aware that they have above average internal communication compared to other kinds of stakeholder groups could be encouraged to spend time developing networks with lay users and bridges, such as hobbyists, who could provide valuable novel information to increase their already strong coordination capacity. Or, media could spend more time connecting internally to help diverse broadcasters keep in touch with what others in their area are doing and help strengthen cross communication and coordination efforts. In particular, identifying agencies or areas that are missing can help stakeholder groups seek out and develop relationships that can fill those gaps and increase warning capacity overall. All of these are made possible when network analytics can grant structural insight into how people are connected and may communicate at a big picture level based on community roles.

Lastly, despite the insights into big picture decision making that the CSN provide, it is important to remember that follower ties are meaningless if people do not use them. A number of emergency management workers noted in the survey that they felt better integration between mass media production and emergency management coordination could help manage public information release and dissemination much more effectively by allowing the two groups to collaborate on their informational needs. As such, simply following users is only the first step. The second, and far more important step, is to get users to communicate through those channels so that interoperability can be achieved. Doing so will require an engaged, conversational, and sharing online presence on behalf of all parties, and a willingness to express needs and expectations on Twitter so that others can meet them as the need to do so arises. The importance of developing network relationships cannot be overstated, as bonds built on trust and transparent communication enable users to cooperate. To this end, formal emergency management groups, media, and the private sector, will need to invest time into safely dismantling organizational policies and practices that restrict communication and coordination with other agencies in a public domain. Overseeing bodies responsible for the integration of information between these groups would also be an asset. For instance, EMBC could mandate its social media unit to be responsible for conveying needs of first responders to media and ensuring stakeholders from all groups can connect. This could be as simply as taking a monthly sample of their follower network and reaching out to those users individually to request their participation in a volunteer retweet training lesson or program.

## 6.5. Warning British Columbia

In sum, the CSN can best assist tsunami early warning in Twitter by providing top level visibility into which communities have access to NTWC warnings, identifying which representatives from stakeholder groups can be coordinated with, assessing and testing the direction and spread of warning through follower ties in advance, and detecting influential opinion leaders in BC who can be instrumental in widespread tweet dissemination as well as coordination with locals. The CSN and survey responses indicate that BC OLs are widely invested in Twitter, likely underestimate their influence in the network, and are willing to be compliant with best practices but are limited by difficulties with using Twitter to connect with publics in British Columbia where Twitter adoption is less widespread and infrastructure is more limited. This lack of familiarity and audience access, coupled with uncertainty about the institutional role of Twitter, is likely the driving force behind the increased desire for broadcasting and for information control. It is this study’s goal to reduce these by providing BC tsunami early warning stakeholders and opinion leaders a toolkit for visualizing and understanding their communication.

# Chapter 7.

# Conclusion: Voices at the Table

This study set out to discover a tsunami early warning network in Twitter in advance of an event and, in finding one, to publicize its stakeholders and structure in a way that can inform academic and practitioner audiences on how that network can best serve tsunami early warning in BC. These findings can hopefully be applied to other risk areas outside of Canada as well. As the data clearly demonstrate, Twitter has a tall order to fill when it comes to disaster communication and tsunami warning is only one line item. The Cascadia Subnetwork analysis provides insight into where warning stakeholders are located relative to risk, what roles those users fill within those locations, and how well those groups are able to communicate with themselves and others relative to best practices outlined in the current literature. The survey further provides insight into how opinion leaders intend to leverage Twitter during an event relative to their current use and perceptions. In particular, the hashtag and content control data are published for the first time from the perspective of a transnational, multi-stakeholder social network, and help to dispel misconceptions about where opinion leaders stand on tsunami warning in Twitter as well as the shared commonalities that supersede country, community type, or stakeholder group. In this way, the survey data help to inform on communication capacity from a ritual, that is social and community, standing, as the network data inform on communication capacity from a structural and geographic perspective. Together, the two methods yield strong evidence that the CSN's current warning capacity includes vulnerable areas that can be reached, but that stakeholder groups, and the social and structural areas that they can reach, need to be expanded to connect information silos and improve warning transfer overall.

This final chapter summarizes the study's many conclusions in regards to their specific relevance to tsunami early warning in British Columbia. It also espouses a number of technical and design challenges the study faced and that require further study to ensure the accuracy of the findings provided. It ends with a discussion of future directions based on emerging solutions and conclusions from the network and survey data. Its ultimate goal is to convey to encourage disaster management researchers and practitioners alike to adopt proactive relationships and communication strategies that are warning conducive.

## 7.1. Significant Findings Summary

First, the CSN is a network of Twitter users who are vested in receiving tsunami warnings from NTWC. Those members show a near even split between British Columbia (57%) in Canada and Alaska, Washington, Oregon, and California (43%) in the United States. However, BC users made up 84% of all NTWC's Canadian followers whereas AK, WA, OR, and CA made up just 43% of US followers. This concentration of followers in BC may be because BC users have less access to tsunami warning Twitter accounts, excepting @emergencyinfobc which obtains its data from NTWC. Consequently, BC users are highly reliant on @NWS_NTWC as a warning source and likely make up a large portion of identifiable tsunami warning stakeholders for BC in Twitter. The CSN thus quite certainly contains the first lines of communication between NTWC and the rest of BC.

Second, BC's presence in the CSN is significant, especially for rural and high-risk tsunami notification zones. The finding proves Twitter networks can be mapped to study tsunami early warning pathways to remote communities in BC. The CSN is a low density network that lacks community structure but contains smaller groups that can communicate. The CSN is predominately urban (85%) and contains nine distinct stakeholder groups: academia (4%), first response (4%), government (7%), hobbyist (4%), media (13%), private sector (13%), public sector (5%), professional (16%), and citizens (34%). Academics, hobbyists, and professionals were determined to act like *information brokers*, media and government as *information boosters*, first response and public sector as *information coordinators* and private sector and citizens as *information seekers*. These descriptive data provide insight into previously invisible links that support the network's stakeholder interoperability. The critical benefit for BC is that they indicate which roles are present in the CSN, how BCs users contribute to this roster, and how they interconnect.

Third, OLs are particularly better connected and more homophilous than the CSN overall. They are likely to prompt other users to share and follow messages as a result of their increased network influence. While the CSN is characterized by citizens, professionals, and the private sector, its OL subset has more influential members in government, media, and first response, and fewer citizens and professionals, indicating many more users in traditional emergency management are influentials. According to the survey responses, 76% of OLs live in coastal locations and the 70% of these OLs are influential strong ties, meaning they are closely connected to other users in the CSN. In contrast most influential weak ties who can reach communities outside the CSN are either non-coastal or in the US. Coastal OLs are more hazard aware, more influential, and value Twitter for tsunami warning more. Furthermore, media system dependency predicts that proximity to and awareness of risk increase the likelihood coastal users will turn to Twitter during a tsunami. As such, coastal OLs will be critical points of contact who should be able to influence the influx of inquiring users to share or otherwise act on information because of their informal ties and trustworthiness. However, BC's OLs are more likely to be information coordinators or seekers rather than broadcasters, and are less influential overall. As a result, despite being influential, most BC OLs' range extends to small communities of like-minded peers. This finding is significant because it indicates BC OLs are less able to influence other users, especially non-CSN users, seeking information should a tsunami strike the PNC.

Fourth, BC rural users are socially and structurally isolated. BC makes up the bulk (70%) of rural users. They are BC's best internally connected group. They communicate well but are the weakest bridge or external communicator. It is notable socially and geographically isolated OLs are also the most tightly tied. These metrics may be explained by stakeholder distributions. NTWC has more private sector, first response, and citizen followers in BC. In particular, BC has more rural first response and public sector users and more urban professional, citizen, and private sector users. First responders and the public sector also have strong internal cohesion. Thus, BC's greater rural cohesion is likely related to the efforts of rural first responders and the public sector to share NTWC content. Similarly, BC's increased urban professional and private sector OLs indicate greater seeking and bridging communication compared to the US, specifically from public, private sector and media to hobbyists, academics, and citizens. The prevalence of these groups and their follower patterns may explain why BCs OLs are better positioned to seek or share information to their own groups, rather than across groups and at-risk areas.

Fifth, at the same time rural OLs report the highest influence in BC and a strong desire to participate in tsunami early warning. They are also the most open to sharing hashtag and content control between emergency management and publics, and express a genuine desire for community development in Twitter. However, while these intentions are in line with the best practices in the literature in regards to increasing warning reach and uptake through dedicated follower networks built on mutual user interaction, rural users' lack of external ties will likely cause difficulty reporting or receiving from emergency management, which creates an interoperability barrier in the event of a tsunami. This finding identifies a clear gap between emergency and non-emergency management that urgently needs addressing. It also shows how network and content analysis data together can illuminate longstanding issues of reaching rural publics in data-driven ways.

Sixth, in all BC's structural capacity in the CSN is most conducive to *information seeking*. In the CSN, BC's non-reporters act like information seekers, likely due to their high citizen base. They are not strong broadcasters, coordinators, or bridges but do have ties to myriad sources. Urban users are more like broadcasters, with high closeness centrality indicating strong external reach within the province. Rural groups, as mentioned, are coordinators as their internal communication and reciprocity is strong. In all, BC's part in the CSN is most conducive to seeking because of its low overall interconnectivity to the US or even across groups within the Province. Most significantly, rural and urban users function better independently, which means their capacity to warn BC-wide is limited. Perhaps a larger coastline and smaller populace mean BC's increased users and stakeholder differences mark larger rural and urban divides or a greater reliance on Twitter and NTWC relative to limited notification source or resource availability. In either case, highly specified audience targeting is needed in order for CSN users in BC to warn, such as knowing where users and who they follow relative to a hazard. Another method would be to leverage connections between urban broadcasters and rural coordinators to enhance information flow nationally and in the CSN, but this would require users to actively work on making strategic mutual connections to poorly tied areas.

Seventh, compared to OL self-reports CSN stakeholder group assignments were 64% accurate (and 70% or higher for academics, government, first response, and media) and municipality assignments were 69% accurate (85% for BC rural OLs and 71% for US rural OLs municipalities and 100% for country or provincial and state locations). These findings are significant because they suggest CSN data can be compared to OL self-report data to understand user communication in BC. Although further testing is needed to refine the content analysis dictionary used to define these locations and groups, if improved these metrics could provide a reliable method for studying pre-event warning networks based on user connectivity and stakeholder group affiliation. To this end, the most significant methodological finding to emerge from this study is opinion leader detection in these early warning networks. Network influence increases alongside perceived influence. The CSN's method measures general influence using ranked averages from multiple metrics constrained by location. In this, it has successfully produced a new method for OL detection that with further testing could help shape a standardized theory of influence in Twitter that resolves the million follower fallacy and related preferential biases that occur when ascribing influence to a single behavior. Making methods for detecting influential opinion leaders accessible can help emergency mangers, or any interested stakeholder, enlist the help of users who can help ensure warnings reach their intended audiences.

Eighth, influential weak ties who can prompt warning dissemination in networks outside the CSN are rare, and although strong tie influence within the CSN rivals the US, BC users overall are less able to prompt warnings compared to US users. That said, BC's rural OLs were the most confident about their influence and as such are the most able to prompt their followers to share warnings in BC. As well, BC's non-coastal weak tie OLs are less common, but also more likely to extend influence outside the CSN. BC rural OL's higher influence may be attributed to greater private and public sector and first response OL presence in BC rural communities. As such, these groups are vital sources for BC's few influential weak ties to access BC communities outside the CSN. Gaining their assistance lies in letting these users know they are more influential than they perhaps realize, and that their position on the CSN's peripheral means they are important contacts for outside networks, especially in remote, rural, or isolated areas. Finally, weak tie OLs in BC also tend to belong to stakeholder groups not associated with traditional disaster management. While these weak ties may still be able to reach outside networks, their ability to influence behavior in those networks may be limited about a lack of knowledge about their role or ability to assist in warning, and formal relationships with these key contacts should be encouraged to increase their warning efficacy.

Ninth, BC opinion leaders are mostly interested in sharing hashtag and content control between publics and emergency management. However, they are much more likely than the US to want to maintain control of these communication lines specifically within emergency management. Furthermore, BC OLs are more likely to see Twitter as having more limitations, to prefer benefits outside of response and recovery, such as general communication, and to see Twitter as more beneficial for broadcasting purposes such as general awareness communication despite strong evidence that Twitter can be used to coordinate or assist response if locals are known (Latonero & Schlovski, 2011; Hughes & Palen, 2009). For example, it is striking that OLs, and especially BC OLs, rated Twitter low for fundraising benefits given that fundraising for Haiti earthquake relief in 2010 was massively successful in large part thanks to Twitter circulation and mobile devices (Lobb et. al, 2012). This finding is significant because it sheds light on a distinct cultural communication preference in BC that suggests OLs are holding back in terms of adopting participatory and interactive community solutions, preferring to maintain communication practices that reinforce informational silos while at the same time recognizing the need to reduce them. While this may be due to lack of a strong last-mile userbase, the presence of non-emergency response rural users in high risk tsunami notification zones underlies this argument and indicates opportunities for potential relationship growth.

Tenth and finally, citizen OLs often lacked alternative warning sources outside the CSN, and although they spend a good deal of time seeking out disaster information and are interested in it, are less likely see benefits outside of broadcasting, or limitations. They report being unfamiliar with the kinds of communication Twitter can foster. To bring this group into the fold further so as to reduce time spent looking for information, and to improve their capacity to assist in sharing and action, emergency management should strive to engage them in the day to day practicalities and knowledge about warnings in Twitter. Certainly, strategies that make Twitter easier to manage and encourage lay participation would address the lack of lay investment, extend the range of Twitter benefits, and reduce perceptions of limitation as well. Dedicating personnel to manage aggregate data from social networks for rapid decision making and to perform the role of public information officer would greatly reduce a number of concerns users placed in misinformation and audience targeting for Twitter as well. However, it is interesting that most non-lay OLs stressed the need for a greater relationship with traditional media as their greatest priority, without mention of the many other stakeholders in the CSN who interested in participating. A greater mutual awareness between all stakeholders is needed, and something this study has endeavored to address by providing visibility into

CSN membership. Another, extended contribution from this newfound visibility is that emergency management can utilize CSN connections to build a better integrated communication system that leverages accounts across communities, stakeholder groups, and perhaps even countries to enhance emergency management programs and policies.

## 7.2. Limitation of Scope

The study faced a number of design and methodological limitations, some of which can be addressed through replication and continued research. One major challenge for the profile content analysis was the lack of an established and tested key word dictionary for identifying disaster mitigation stakeholder groups. This absence made stakeholder detection lengthy, over a month to complete manually, and comparisons against additional studies are needed to validate the categories used. For instance, both the citizen and professional groups in this study are over inflated as a result of a lack of profile information available to classify these users into other, more specific groups. Many users in each were classified correctly, but many others may have been misplaced as a result of too little information. A more refined strategy for distinguishing stakeholder groups in a timely fashion is needed.

Another problem came from sampling network data. This study used a form of purposive sampling (Rothenberg, 1995). Its nominalist sampling frame uses formal criteria to identify network boundaries by their analytical significance, even though they may not be a socially organized or recognized group (Lauman et al., 1989; Scott, 2013). The advantage to this method is that participants are more geographically and socially diverse. However, the incomplete ego-centric networks it produces prohibit inferential statistical analyses (Rothenberg, 1995; Scott, 2013). For instance, by October 11, 2015 @NWS_NTWC's follower count had risen to 34,849, reducing sample coverage to 28%. As time passes, new followers join, perhaps old ones leave, and links between users undoubtedly change. Thus, this sample is a snapshot of NTWC's network at the time of capture, no more and no less. Alone, it cannot speak to the current network's composition or even to the total network it was pulled from at the time. In truth, validity and generalizability can never be fully addressed in large social networks because they are in constant flux (Rothenberg, 1995). An unknown population shatters the concept of *N* on which all inferential statistics is based. However, sampling networks by common role-based attributes, as this study does, at least allows comparisons between groups (Burt, 1984; Scott, 2013). In fact, research on Twitter use during disasters indicates that grouping users by role clarifies common ways stakeholders communicate (Burgess & Bruns, 2012). Holding role based observations against empirical, ethnographic population assessments offers better insight into networks than qualitative or statistical inference alone (Rothenberg, 1995). Thus, the mixed methods approach in this study enables generalizations for a larger population.

Still another issue is the limited design scope. The CSN does not study live communication but the potential for communication based on follower ties. It can only make estimates about information flow based on the structure of those lines. Similarly, the metrics to define opinion leaders, while verified against survey responses, require further rigorous testing. This approach does not connect predicted Twitter influence to persuasive dissemination because live communication was not studied. It would also have been valuable to cross tabulate survey responses down by country, community, and stakeholder to see, for example, what rural first responders in BC think about hashtags. However, this level of fine detail requires a much larger sample than was available. The scope for these pursuits is sufficiently larger than this thesis can account for and are best left to additional studies.

Lastly, CSN data cannot conclusively prove world risk society or media systems dependency motivate social media use. Communication to mitigate disasters is deeply embedded in the concepts of a world risk society and media systems dependency, and stands as the motivation for conducting this research. Social media driven early warning during disasters is one expression of disasters as communicated events in a network society, and it is through understanding the total contribution of all users in a network in the context of these theories that mitigation can be achieved. This cross-section of NTWC's network offers a comparative baseline that can allow the relationships between communication, media effects, and theory to be studied as interdependent phenomenon. Its results and recommendations can guide future community research or qualify larger, big data studies of tsunami pre-event networks. It also identifies methods for detecting stakeholders and opinion leaders who may reach target audiences as a way to pre-emptively strengthen the CSN's overall reach and efficacy. These findings can be held against future ethnographic research to gauge how opinions and distributions remain consistent or change over time. Most of all, the data are springboard extending Twitter tsunami warning network research in BC, an entirely new avenue for pre-event research in Canadian disaster mitigation.

## 7.3. Future Directions

Looking forward, there may be ways opinion leaders can achieve the improvements to Twitter that will make response, recovery, and early warning communication more efficient for tsunamis and other disasters. That is, by synthesizing their responses with network data to determine how the two can inform each other, and comparing responses to best practices established in the literature, we can give Twitter stakeholders insight into areas they can change, and where change needs to be pushed for collectively to improve response and recovery across the board. That has been the goal throughout this project, and there are a number of future directions that emerge from it.

Foremost, the CSN is limited by looking only at immediate NTWC followers. Now that the CSN has been confirmed as a tsunami early warning network for the PNC, and a system for sampling followers and detecting OLs who are weak ties has been established, future research should examine OL follower networks, with a specific focus on identifying users in remote, at-risk communities as well as other forms of vulnerability. Paired studies with @emergencyinfobc would help identify notification overlap and help expand the known range for communication between these two sources. This data would enable emergency managers to get a sense of where NTWC warnings can travel outside the CSN. With this information in hand, it would be possible to develop and test transmedia and tertiary communication strategies. In particular, a community watch system that is volunteer driven and formally establishes volunteers as citizen sensors within communities would help make the CSN a warning network that was interpersonally driven and inclusive, helping to move it away from the broadcast model that predominates in BC. These points of contact could also employ other media, including ICTs or door-to-door warning for communities who are not linked in to the CSN warning system directly. Conducting additional network analyses on Atlantic, Mexican, and Puerto Rican NTWC followers would allow the results of this study to extended and globally contextualized within NTWC’s complete warning range as well, providing a detailed pictured of warning capacity at a global scale.

Future research into opinion leaders' followers could then be applied to alert testing. With an available baseline for comparison, false alerts could be run through Twitter stemming from the NTWC and network analysts could track where they travel relative to tsunami risk, and at what speeds through follower networks. If volunteers from all stakeholder groups were registered to participate, those users could be surveyed to determine what reasons they had and methods they used to contact people outside Twitter, and from there a much more complete understanding of warning reach could be achieved. The data could then be used to monitor how the CSN behaves in response to warnings relative to their network structure, findings which could then be used to strategically adjust network paths to improve communication flow. To be fully effective, the results of these tests and the recommendations that emerge from them would need to be published online and provide solutions that would help all stakeholders close the loop on communication in the network. As well, requesting program volunteers to temporarily turn on location on their devices, if they are comfortable doing so, to help coordinate response efforts and locate on the ground users would help tremendously in filtering through Twitter noise to locate and work with key contacts. Establishing bonds with other stakeholder groups so that they are aware of emergency management's needs to collaborate with locals may also encourage those groups to assist in connecting first responders with those audiences. In particular, identifying opinion leaders and soliciting their help in conveying and testing warnings is critical. These strategies can all be tested and modelled using CSN data.

Finally, in order to foster the level of user engagement needed to ensure participatory communities develop quickly around warning content, emergency management officials will need to develop a system for round the clock Twitter first response, including dedicated teams for creating, managing, analyzing and responding to content. Establishing formal roles for social media as an early warning system would go a long way towards reducing the difficult process of update management and accuracy control because enough resources would be invested to do so. These users would need to seek out and partner with other social media coordinators that other stakeholder groups have established. Developing and publicizing a formal network strategy that incentivizes those groups to participate and communicate with first response collaboratively would be tremendously useful for establishing those bonds. From there, emergency management should continue investing time developing public relations with Twitter users and actively seeking out users in at risk areas who are not already a part of their circuit. This does not necessarily mean following indiscriminately or blasting out tweets in order to be heard. Rather it means conversing with and inviting users to be part of the CSN and its extended network as a public safety measure, and actively working to build relationships of trust that supersede physical location so that a true online community or public space is established.

With those relationships in place, it becomes easier to push for partnerships with other stakeholder groups, and potentially even with Twitter. Moving away from the idea of Twitter as a news platform and into the idea of Twitter as a horizontal ICT system transforms the site from a news or entertainment provider to a global public utility. This kind of transition is entirely with Beck's (2006) and Castell's (2008) arguments that a world risk society is a transnational society, and that only organizations that adopt global network agendas can be poised to mitigate disasters in the digital era. Treating Twitter as a public utility or resource in practice, if not in policy, would help justify infrastructure development in hard to reach communities that want to use this technology to connect to the wider online community outside their areas. Recasting Twitter as a public utility may also make it easier to partner with the site during emergencies, as many opinion leaders have suggested. Location based alerts that do not get pushed down in feeds, or special notification sounds, could both assist in this endeavor.

After all is said and done, any study in media effects is ultimately a study in ideology. In this domain, the question of how Twitter can best assist tsunami mitigation in British Columbia emerges as a multifaceted one. Its breadth speaks to Beck's (1992) world risk society in that users are geographically positioned to coordinate outside of spatiotemporal or social bounds that would otherwise prevent communication, notwithstanding vulnerabilities that can limit participation. As such, CSN followers may be able to assist in disaster mitigation provided users see a warning in time and can transmit it to target audiences directly or indirectly through user networks or tertiary ICTs. In this sense, risk society has never been better positioned to mitigate disasters through communicative practices such as tsunami early warning. It is up to us to recognize how those networks can and should function independently from national or regional systems in order to maximize their communication capacity, and by extension life-saving opportunities.

# References


Acar, A., & Muraki, Y. (2011). Twitter for crisis communication: lessons learned from Japan's tsunami disaster. *International Journal of Web Based Communities*, 7(3), 392-402. doi: 10.1504/IJWBC.2011.041206

Abe, Y. (n.d.) Analyzing the Fukushima Nuclear Crisis through uses of social media: A short essay on a work in progress. *An STS Forum on Fukushima*. URL: http://bit.ly/1OUD9Rp

Adam, B., Beck, U., & Van Loon, J. (Eds.). (2000). *The risk society and beyond: critical issues for social theory*. Sage Publications Ltd., London: United Kingdom. URL: http://bit.ly/1McYG7l

Albrechtslund, A. (2008). Online social networking as participatory surveillance.*First Monday*, *13*(3). doi: http://dx.doi.org/10.5210/fm.v13i3.2142

AlFalahi, K., Atif, Y., & Abraham, A. (2014). Models of Influence in Online Social Networks. *International Journal of Intelligent Systems*, *29*(2), 161-183. doi: 10.1002/int.21631

Anderson, P. (2006). British Columbia tsunami warning methods: A toolkit for community planning. *Telematics Research Lab.* URL: http://bit.ly/1OATYNY

Anderson, P. (2010, July). *Symposium on Enhancing Tsunami Warning Along North America's Northwest Coast: Reaching the Last Mile.* Cascadia Region Earthquake Working Group. URL: http://bit.ly/1VOObsx

Anderson, P. & Gow, G.A. (2004). *Tsunamis and Coastal Communities in British Columbia: An Assessment of the BC Tsunami Warning System and Related Risk Reduction Practices*. Public Safety and Emergency Preparedness Canada. URL: http://bit.ly/1K9kRV3

Anderson, P. (2015). Improving end-to-end tsunami warning for risk reduction on Canada's West Coast. Canadian Safety and Security Program, Defence Research and Development Canada, Ottawa, Ontario.

Anger, I., & Kittl, C. (2011, September). Measuring influence on Twitter. In*Proceedings of the 11th International Conference on Knowledge Management and Knowledge Technologies* (p. 31). ACM. doi: 10.1145/2024288.2024326

Athukorala, P. C., & Resosudarmo, B. P. (2005). The Indian Ocean tsunami: economic impact, disaster management, and lessons. Asian Economic Papers, 4(1), 1-39. doi:10.1162/asep.2005.4.1.1.

Austin, L., Fisher Liu, B., & Jin, Y. (2012). How audiences seek out crisis information: Exploring the social-mediated crisis communication model. *Journal of Applied Communication Research*, *40*(2), 188-207. doi: 10.1080/00909882.2012.654498

Bailey, G., & Hackett, R. (1997). Newswatcher's guide to content analysis. *Newswatch Canada.* URL: http://bit.ly/10SYtIR

Bakshy, E., Hofman, J. M., Mason, W. A., & Watts, D. J. (2011, February). Everyone's an influencer: quantifying influence on twitter. In *Proceedings of the fourth ACM international conference on Web search and data mining* (pp. 65-74). ACM. doi: 10.1145/1935826.1935845

Ball-Rokeach, S. J., & DeFleur, M. L. (1976). A dependency model of mass-media effects. *Communication research*, *3*(1), 3-21. doi: 10.1177/009365027600300101

Ball-Rokeach, S. J. (1985). The origins of individual media-system dependency a sociological framework. *Communication Research*, *12*(4), 485-510. doi:10.1080/15205436.1998.9676398

Basher, R. (2006). Global early warning systems for natural hazards: systematic and people-centred. *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences*,*364*(1845), 2167-2182. doi: 10.1098/rsta.2006.1819

Basu, R. (2015, Mar 10). News Coverage of Fukushima Disaster Found Lacking. *American University.* URL: http://www.american.edu/media/news/20150310-Fukushima.cfm

BBC News (2011, Dec 26). Fukushima accident: disaster response failed – report. *BBC News Asia.* URL: http://www.bbc.com/news/world-asia-16334434

Beck, U. (1992). On the logic of wealth distribution and risk distribution. In *Risk society: Towards a new modernity* (1). London, UK: Sage Publications.

Beck, U. (2006). World risk society as cosmopolitan society?: Ecological questions in a framework of manufactured uncertainties. *Theory, Culture & Society*, *13,* 1-32. doi: 10.1177/0263276496013004001

Beck, U. (2009). *World at risk*. Polity Press, Cambridge: United Kingdom.

Bergmann, J, Egner, H., & Wulf, V. (2010). Communicating Disaster. *Centre for Interdisciplinary Research.* URL: http://bit.ly/1L3iVCG

Berkhin, P. (2005). A survey on pagerank computing. *Internet Mathematics*,*2*(1), 73-120. doi: 10.1080/15427951.2005.10129098

Blaikie, P., Cannon, T., Davis, I., & Wisner, B. (2014). *At risk: natural hazards, people's vulnerability and disasters*. Routledge, New York: New York.

Bobkowski, P., & Smith, J. (2013). Social media divide: characteristics of emerging adults who do not use social network websites. *Media, Culture & Society*, *35*(6), 771-781. doi: 10.1177/0163443713491517

Bogart, N. (2013, June 21). Calgary flooding puts police in Twitter jail, crashes city website. *Global News.* URL: http://bit.ly/1JkWIeJ

Brabham, D. C. (2013). *Crowdsourcing.* Cambridge: The MIT Press.

Broenner, C. (2012) Appropriate Interoperability-from Technical to Socio-Technical.*AGSE 2012–FOSS4G-SEA*, 197. URL: http://bit.ly/1JVzV9F

Brozak, S. & Bassman, H. (2011, Apr 6). Fukushima: A Nuclear Threat to Japan, the U.S. and the World. *ABC News.* URL: http://abcn.ws/1L3CEyr

Bruns, A., Burgess, J. E., Crawford, K., & Shaw, F. (2012). # qldfloods and@ QPSMedia: Crisis communication on Twitter in the 2011 south east Queensland floods. *Queensland University of Technology: Australia.* URL: http://bit.ly/1LYiU1F

Bruns, A., & Liang, Y. E. (2012). Tools and methods for capturing Twitter data during natural disasters. *First Monday*, *17*(4). URL: http://bit.ly/1Qpwj4k

Burgess, J., & Bruns, A. (2012). Twitter archives and the challenges of" Big Social Data" for media and communication research. *M/C Journal*, *15*(5). URL: http://bit.ly/1L3j49p

Burgess, J., & Bruns, A. (2012). Twitter archives and the challenges of" Big Social Data" for media and communication research. *M/C Journal*, *15*. URL:http://bit.ly/1hZnS3M

Burt, R. S. (1984). Network items and the general social survey. *Social networks*, *6*(4), 293-339. doi:10.1016/0378-8733(84)90007-8

Boyd, D., & Crawford, K. (2012). Critical questions for big data: Provocations for a cultural, technological, and scholarly phenomenon. *Information, communication & society*, *15*(5), 662-679. doi: 10.1080/1369118X.2012.678878

Calhoun, C. (2010). *The idea of emergency: Humanitarian action and global (dis) order* (pp. 29-58). New York: Zone Books. URL: http://bit.ly/1EPles9

Canadian Internet Registration Authority (2014). The Canadian Internet. *Canadian Internet Registration Authority.* URL: http://bit.ly/1XNH2KQ

Canadian Red Cross. (2012). Social media during emergencies. URL: http://bit.ly/1zdtQVR

Carey, J. W. (2009). *Communication As Culture*. (Revised ed.). Routledge, New York.

Castells, M. (2008). The new public sphere: Global civil society, communication networks, and global governance. *The Annals of the American Academy of Political and Social Science,* 616(1), 78-93. doi: 10.1177/0002716207311877

CBC News. (2010, January 14). Social media help find quake survivors. CBC News. URL: http://bit.ly/1VRlOb6

CBC News. (2012, October 29). B.C. tsunami warning came 39 minutes after U.S. alert. *CBC News.* URL: http://bit.ly/1OAUDiu

Chandler, D. (1994). *The Transmission Model of Communication.* URL: http://bit.ly/1EWMkxl

Cha, M., Haddadi, H., Benevenuto, F., & Gummadi, P. K. (2010). Measuring User Influence in Twitter: The Million Follower Fallacy. *ICWSM*, *10*(10-17), 30.

Chatfield, A., & Brajawidagda, U. (2012). Twitter tsunami early warning network: a social network analysis of Twitter information flows. ACIS 2012 : Location, location, location : Proceedings of the 23rd Australasian Conference on Information Systems 2012 (pp. 1-10). Australia: Deakin University. URL: http://bit.ly/1K9lhuR

Chhotray, V., & Few, R. (2012). Post-disaster recovery and ongoing vulnerability: Ten years after the super-cyclone of 1999 in Orissa, India. *Global environmental change*, *22*(3), 695-702. doi:10.1016/j.gloenvcha.2012.05.001

Clague, J. J., Munro, A., & Murty, T. (2003). Tsunami hazard and risk in Canada. *Natural Hazards*, *28*(2-3), 435-463. doi: 10.1023/A:1022994411319

Cole, T. W., & Fellows, K. L. (2008). Risk communication failure: A case study of New Orleans and Hurricane Katrina. *Southern Communication Journal*, *73*(3), 211-228. doi:10.1080/10417940802219702

Collins, M., Kapucu, N. (2008). Early warning systems and disaster preparedness and response in local government, *Disaster Prevention and Management: An International Journal*, 17(5), 587 – 600. doi: 10.1108/09653560810918621

Comfort, L. K., & Haase, T. W. (2006). Communication, coherence, and collective action the impact of hurricane katrina on communications infrastructure. *Public Works management & policy*, *10*(4), 328-343. doi: 10.1177/1087724X06289052

Cottle, S. (2014). Rethinking media and disasters in a global age: What's changed and why it matters. *Media, War & Conflict*, *7*(1), 3-22. doi: 10.1177/1750635213513229

Cottle, S. (2011). Taking global crises in the news seriously: Notes from the dark side of globalization. *Global Media and Communication*, *7*(2), 77-95. doi: 10.1177/1742766511410217

Crowe, A. (2012). *Disasters 2.0: The application of social media systems for modern emergency management*. CRC press.

Dash, N., & Gladwin, H. (2007). Evacuation decision making and behavioral responses: Individual and household. *Natural Hazards Review*, *8*(3), 69-77. URL: http://bit.ly/1IZ6eD1

Doan, S., Vo, B. K. H., & Collier, N. (2012). An analysis of Twitter messages in the 2011 Tōhoku Earthquake. In *Electronic Healthcare*, 58-66. Springer Berlin Heidelberg. URL: http://bit.ly/1VOOKCB

Doctors Without Borders (2010 December 14). Twitter Calls NBC Anchor Ann Curry's Tweet about MSF in Haiti "Most Powerful Tweet of 2010. *Doctors Without Borders.* URL: http://on.fb.me/1Lt3PpW

Dombrowsky, W. R. (1995). Again and Again: Is a Disaster What We Call a 'Disaster'? *International Journal of Mass Emergencies and Disasters*, *13*(3), 241-254. URL: http://bit.ly/1FyJkSO

Domingos, P., & Richardson, M. (2001, August). Mining the network value of customers. In *Proceedings of the seventh ACM SIGKDD international conference on Knowledge discovery and data mining*, 57-66. ACM. doi: 10.1145/502512.502525

Dubois, E., & Gaffney, D. (2014). The Multiple Facets of Influence Identifying Political Influentials and Opinion Leaders on Twitter. *American Behavioral Scientist*, *58*(10), 1260-1277. doi: 10.1177/0002764214527088

Earle, P., Guy, M., Buckmaster, R., Ostrum, C., Horvath, S., & Vaughan, A. (2010). OMG earthquake! Can Twitter improve earthquake response? *Seismological Research Letters*, *81*(2), 246-251. doi: 10.1785/gssrl.81.2.246

EM-DAT (2015). The international disaster database. *Centre for Research on the Epidemiology of Disasters – CRED.* URL: http://www.emdat.be/database

Erbring, L., Goldenberg, E. N., & Miller, A. H. (1980). Front-page news and real-world cues: A new look at agenda-setting by the media. *American Journal of Political Science*, 16-49. doi: 10.2307/2110923

Everett, M. G., & Borgatti, S. P. (2005). Extending centrality. *Models and methods in social network analysis*, *35*(1), 57-76. URL: http://bit.ly/1iya5BY

Faber, H. (2013, August 14). Canadian social media statistics 2013. *WebFuel*. URL: https://www.webfuel.ca/canadian-social-media-statistics-2013/

Faustino, J.D., Brooke L. & Yan, J. (2012). Social media use during disasters: A review of the Knowledge base and gaps. *Final Report to Human Factors/Behavioral Sciences Division, Science and Technology Directorate, U.S. Department of Homeland Security: START*. URL: http://bit.ly/1JXgKi1

Flew, T. & Smith, R. (2011) *New media: An introduction* (1st Canadian ed.)*.* Don Mills: Oxford University Press.

Finucane, M., Alhakami, A., Slovic, P., & Johnson, S. (2000). The affect heuristic in judgments of risks and benefits. *Journal of behavioral decision making, 13(1),* 1-17. URL: http://bit.ly/1pN5FHT

First Nations Technology Council. (2015, June 14). Tribal Journeys to Bella Bella 2014. *First Nations in British Columbia.* URL: http://bit.ly/1OebppJ

Fox, N. (1999). In *Risk and sociocultural theory - New directions and perspectives*. Lupton, D. (Eds.). 12-33. URL: http://bit.ly/1MVxPtQ

Garcia-Gavilanes, R., Mejova, Y., & Quercia, D. (2014, February). Twitter ain't without frontiers: Economic, social, and cultural boundaries in international communication. In *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing*, 1511-1522. doi: 10.1145/2531602.2531725

Garnett, J. L., & Kouzmin, A. (2007). Communicating throughout Katrina: Competing and complementary conceptual lenses on crisis communication.*Public Administration Review*, *67*(s1), 171-188. doi: 10.1111/j.1540-6210.2007.00826.x

Garret, T., & Sobel, R. (2003). The political economy of FEMA disaster payment*. Economic Inquiry*, 41(3), 496-509. doi: 10.1093/ei/cbg023

Gassebner, M., Keck, A., & Teh, R. (2010). Shaken, not stirred: the impact of disasters on international trade. *Review of International Economics*, *18*(2), 351-368. doi: 10.1111/j.1467-9396.2010.00868.x

Glik, D. (2007). Risk communication for public health emergencies. *Annual Reviews in Public Health, 28,* 33-54. doi: 10.1146/annurev.publhealth.28.021406.144123

Goggins, S., & Petakovic, E. (2014). Connecting Theory to Social Technology Platforms A Framework for Measuring Influence in Context. *American Behavioral Scientist*, 0002764214527093.  doi: 10.1177/0002764214527093

Goggins, S. P., Mascaro, C., & Valetto, G. (2013). Group informatics: A methodological approach and ontology for sociotechnical group research.*Journal of the American Society for Information Science and Technology*,*64*(3), 516-539. doi: 10.1002/asi.22802

Gore, M., Siemer, W., Shanahan, J., Schuefele, D., & Decker, D. (2005). Effects on risk perception of media coverage of a black bear-related human fatality. *Wildlife Society Bulletin, 33(2),* 507-516. doi: 10.2193/0091-7648(2005)33[507:EORPOM]2.0.CO;2

Guy, M., Earle, P., Ostrum, C. Gruchalla, K., & Horvath, S. (2010). Integration and dissemination of citizen reported and seismically derived earthquake information via social network technologies. *Lecture Notes in Computer Science, 6065*, 42-53. doi: 10.1007/978-3-642-13062-5_6

Hagiwara, A. T., & Sugiyarto, G. (2005, June). Poverty Impact of the Tsunami: An initial assessment and scenario analysis. In *4th PEP research network general meeting, Colombo* (pp. 13-17). URL: http://bit.ly/1JXgZcR

Haight, M., Quan-Haase, A., & Corbett, B. A. (2014). Revisiting the digital divide in Canada: the impact of demographic factors on access to the internet, level of online activity, and social networking site usage. *Information, Communication & Society*, *17*(4), 503-519. doi: 10.1080/1369118X.2014.891633

Hannigan, J. (2012). *Disasters without borders.* Cambridge, UK: Polity Press.

Hansen, D., Shneiderman, B., & Smith, M. (2009). Analyzing social media networks: Learning by doing with NodeXL. *Computing*, *28*(4), 1-47. URL: http://archives.cerium.ca/IMG/pdf/Les_analyses_de_reseaux_avec_NodeXL.pdf

Hartman, C. W., & Squires, G. D. (Eds.). (2006). *There is no such thing as a natural disaster: Race, class, and Hurricane Katrina*. Taylor & Francis, New York.

Herring, S. C. (2004). Content analysis for new media: Rethinking the paradigm. In *New research for new media: Innovative research methodologies symposium working papers and readings* (pp. 47-66). University of Minnesota School of Journalism and Mass Communication. URL: http://bit.ly/12plA1K

Hemsley, J., & Eckert, J. (2014, January). Examining the Role of" Place" in Twitter Networks through the Lens of Contentious Politics. In *System Sciences (HICSS), 2014 47th Hawaii International Conference on* (pp. 1844-1853). IEEE. doi:10.1109/HICSS.2014.233

Hjorth,L. & Kim, K.Y. (2011). The mourning after: a case study of social media in the 3.11 earthquake disaster in Japan. *Television and New Media, 12,* 552-559. doi:10.1177/1527476411418351

Hou, L., & Shi, P. (2011). Haiti 2010 earthquake – How to explain such huge losses? *Int. Journal of Disaster Risk Science*, *2*, 25-33. doi: 10.1007/s13753-011-0003-x

Hughes, A. L., Palen, L., Sutton, J., Liu, S. B., & Vieweg, S. (2008). Sight-Seeing in Disaster: An Examination of On-Line Social Convergence. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM)*. URL: http://amandaleehughes.com/OnlineConvergenceISCRAM08.pdf

Hughes, A. L., & Palen, L. (2009). Twitter adoption and use in mass convergence and emergency events. *International Journal of Emergency Management*, 6(3), 248–260. doi: 10.1504/IJEM.2009.031564

Insights West. (2013, April 18). Your insights on social media in BC. *Insights West*. URL: http://www.insightswest.com/news/your-insights-on-social-media-in-bc/

Insights West. (2014, June 2014). Your insights on social media in BC. *Insights West*. URL: http://www.insightswest.com/news/your-insights-on-social-media-in-bc/

Jung, J. Y., & Moro, M. (2014). Multi-level functionality of social media in the aftermath of the Great East Japan Earthquake. *Disasters*, *38*, 123-143. doi: 10.1111/disa.1271

Justice Institute of British Columbia (2010). *Introduction to Emergency Management in Canada*. Canada: Library and Archives Canada.

Katz, E. (1957). The two-step flow of communication: An up-to-date report on an hypothesis. *Public opinion quarterly*, *21*(1), 61-78. doi: 10.1086/266687

Katz, E. & Liebes, T.(2007).'No more peace!' How disaster terror and war have upstaged media events. *International Journal of Communication,* 1, 157-166. URL: http://bit.ly/1PfVW9a

Kasperson, R. E., & Kasperson, J. X. (1996). The social amplification and attenuation of risk. *The Annals of the American Academy of Political and Social Science, 545,* 95-105. URL: http://www.jstor.org.proxy.lib.sfu.ca/stable/1047896

Kasperson, R., Renn, O., Slovic, P., Brown, H., Emel, J., Goble, R., Kasperson, J. et al. (1988). The social amplification of risk: A conceptual framework. *Risk analysis, 8(2),* 177-187. doi: 10.1111/j.1539-6924.1988.tb01168.x

Kaplan, A.M. & Haenlein. (2010). Users of the world unite! The challenges and opportunities of doi: social media. *Business Horizons, 53,* 59-68. doi: 10.1016/j.bushor.2009.09.003

Keller, C., Siegrist, M., & Gutscher, H. (2006). The role of the affect and availability heuristics in risk communication. *Risk Analysis, 26(3),* 631-639. doi: 10.1111/j.1539-6924.2006.00773.x

Kellner, D. (2010). Media spectacle and media events: Some critical reflections. In *Media Events in a Global Age*. Couldy, N. Hepp, A. & Krotz, F. (Eds.). Routledge. 76-92. URL: http://bit.ly/1RrLudJ

Kolbe, A., Hutson, R, Shannon, H., Trzcinski, E., Miles, B., Levitz, N., et. al. (2010). Mortality, crime and access to basic needs before and after the Haiti earthquake: a random survey of Port-au-Prince households. *Medicine, conflict and survival*, *26*(4), 281-297. doi:10.1080/13623699.2010.535279

Krikorian, R. (2010, April 18). Map of a Tweet. *Scribd.* URL: http://bit.ly/1ElitrK

Kwak, H., Lee, C., Park, H., & Moon, S. (2010, April). What is Twitter, a social network or a news media? In *Proceedings of the 19th international conference on World wide web* (pp. 591-600). ACM. doi: 10.1145/1772690.1772751

Latonero, M., & Shklovski, I. (2011). Emergency management, Twitter, and social media evangelism. *International Journal of Information Systems for Crisis Response and Management (IJISCRAM)*, *3*(4), 1-16. doi: 10.4018/jiscrm.2011100101

Laumann, E. O., Marsden, P. V., & Prensky, D. (1992). The boundary specification problem in network analysis. *Research methods in social network analysis*, *61*, 87. URL: http://bit.ly/1K9lT3D

Lindsay, B. R. (2011). Social media and disasters: Current uses, future options, and policy considerations (Vol. 41987). *Congressional Research Service*. URL: http://bit.ly/1KXfgVm

Lobb, A., Mock, N., & Hutchinson, P. L. (2012). Traditional and social media coverage and charitable giving following the 2010 earthquake in Haiti. Prehospital and disaster medicine, 27(04), 319-324. doi: 10.1017/S1049023X12000908

Loges, W. E. (1994). Canaries in the coal mine perceptions of threat and media system dependency relations. *Communication Research*, *21*(1), 5-23. doi: 10.1177/009365094021001002

Lowrey (2004) Media Dependency During a Large-Scale Social Disruption: The Case of September 11, Mass Communication and Society, 7:3, 339-357, doi: 10.1207/s15327825mcs0703_5

Lupton, D. (2013). *Risk.* (2nd Ed.). Routledge, United Kingdom: London.

Madden, M. K., & Smith, A. W. (2010). *Reputation management and social media: How people monitor their identity and search for others online*. Pew Internet & American Life Project. URL: http://pewrsr.ch/1F7NIeK

Magrath, J. (2007). Climate Alarm: Disasters increase as climate change bites. *Oxfam Policy and Practice: Climate Change and Resilience*, *3*(2), 1-28. URL: https://www.oxfam.org/sites/www.oxfam.org/files/climate%20alarm.pdf

Manovich, L. (2001). The language of new media. MIT Press, Cambridge: U

Marin, A., & Wellman, B. (2011). Social network analysis: An introduction.*Scott J, Carrington PJ, editors. The SAGE Handbook of Social Network Analysis*, 11-25. URL: http://www2.units.it/dotstoriafil/MARIN%20WELLMAN%202009.pdf

Marx, S. M., Weber, E. U., Orlove, B. S., Leiserowitz, A., Krantz, D. H., Roncoli, C., & Phillips, J. (2007). Communication and mental processes: Experiential and analytic processing of uncertain climate information. *Global Environmental Change, 17(1),* 47-58. doi: 10.1016/j.gloenvcha.2006.10.004

McKinnon, M. (2014, January 23). Canadian digital, social and mobile statistics on a global scale. *Canadian's Internet Business.* URL: http://bit.ly/1ejMFqq

McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual review of sociology*, 415-444. URL: http://bit.ly/1OebUQG

Mendoza, M., Poblete, B., & Castillo, C. (2010, July). Twitter Under Crisis: Can we trust what we RT?. In *Proceedings of the first workshop on social media analytics* (pp. 71-79). ACM. doi:10.1145/1964858.1964869

Middleton, S. E., Middleton, L., & Modafferi, S. (2014). Real-time crisis mapping of natural disasters using social media. *Intelligent Systems, IEEE*,*29*(2), 9-17. doi: 10.1109/MIS.2013.126

Miles, B., & Morse, S. (2007). The role of news media in natural disaster risk and recovery. *Ecological Economics*, *63*(2), 365-373. doi:10.1016/j.ecolecon.2006.08.007

Mileti, D. S., & O'Brien, P. W. (1992). Warnings during Disaster: Normalizing Communicated Risk. *Social Problems*, 40-57. doi: 10.2307/3096912

Miyabe, M., Miura, A., & Aramaki, E. (2012). Use trend analysis of twitter after the great east japan earthquake. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work Companion*, 175-178. doi: 10.1145/2141512.2141571

Murthy, D. (2012). *Twitter: Social Communication in Twitter Age.* Polity Press, Cambridge: United Kingdom.

National Oceanographic and Atmospheric Administration. (2014, December 03). Tsunami warning centre history. *National Tsunami Warning Centre.* URL: http://1.usa.gov/1fUYgwy

Nasseri, A., Turel, M., Yin, Y., & Lai, T. (2014). Study of the impact of a magnitude 9.0 Cascadia Subduction Zone earthquake on British Columbia, Canada. In *Proceedings of the 10th U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering*, Anchorage, Alaska. URL:http://bit.ly/1EWNWai

National Research Council. (2013). Committee on Public Response to Alerts and Warnings Using Social Media: Current Knowledge and Research Gaps. *Computer Science and Telecommunications Board; Division on Engineering and Physical Sciences*, 1–78. URL: http://bit.ly/1ieO3Em

Newman, M. E. (2006). Modularity and community structure in networks.*Proceedings of the National Academy of Sciences*, *103*(23), 8577-8582. doi: 10.1073/pnas.0601602103

Ni, C., Sugimoto, C., & Jiang, J. (2011). Degree, Closeness, and Betweenness: Application of group centrality measurements to explore macro-disciplinary evolution diachronically. In *Proceedings of ISSI* (pp. 1-13). URL: http://bit.ly/1K9m5j8

NodeXL Forum. (2014, June 12). Twitter rate limit. *NodeXL Codeplex.* URL: https://nodexl.codeplex.com/discussions/548386

Nova: Season 32, Episode 15. (2005, Mar 29). The wave that shook the world. *PBS.*

O'Brien, G., O'Keefe, P., Rose, J., & Wisner, B. (2006). Climate change and disaster management. *Disasters*, 30(1), 64-80. URL: http://1.usa.gov/1hngluX

Olenick, D. (2014, March 3). Ellen DeGeneres takes down Twitter, retweet record and Bacak Obama with single selfie. *Tech Times.* URL: http://bit.ly/1UCKZDb

Okabe, D. (February 16, 2011). Social Media and the Great East Japan Earthquake and Tsunami of March 11, 2011. *About Japan*. URL: http://bit.ly/1VCwvyi

Osnos, E. (2011, October 17). LETTER FROM FUKUSHIMA: THE FALLOUT. Seven months later: Japan’s nuclear predicament. *The New Yorker.* URL: http://nyr.kr/1VCwni8

Palen, L. (2008). Online social media in crisis events. *Educause Quarterly*,*31*(3), 12. URL: http://www.educause.edu/ero/article/online-social-media-crisis-events

Pantti, M., Wahl-Jorgensen, K., & Cottle, S. (2012). *Disasters and the Media.*Peter Lang Publishing, New York: New York.

Pinto, A. D. (2010). Denaturalizing “natural” disasters: Haiti’s earthquake and the humanitarian impulse. *Open Medicine*, *4*(4). URL: http://1.usa.gov/1IZ6Fgy

Pingdom. (March 14, 2011). Twitter once again proves its worth in Japan earthquake aftermath. *Pingdom.* URL: http://bit.ly/1L3CU0k

Potts, L., Seitzinger, J., Jones, D., & Harrison, A. (2011). Tweeting disaster: hashtag constructions and collisions. In *Proceedings of the 29th ACM international conference on Design of communication*, 235-240. doi: 10.1145/2038476.2038522

Province of British Columbia. (2015a, June 14). Emergency #hashtag list. *EmergencyInfoBC.* URL: https://www.emergencyinfobc.gov.bc.ca/resources/

Province of British Columbia. (2015b, June 14). Tsunami Notification Zones. URL: http://bit.ly/1L3kjVZ

Province of British Columbia. (2015c, June 14). Infoline Blog. *BC Stats,* 13(44). URL: http://www.bcstats.gov.bc.ca/publications/infoline/13-11-04/Issue_13-44.aspx

Public Safety Canada. (2013). *An Emergency Management Framework for Canada* (Second Edition). URL: http://bit.ly/1IZ6HVS

Quarantelli, E. L. (1998). *What is a disaster?: perspectives on the question*. Psychology Press. Routledge: New York.

Retweet Rank (2014). Frequently asked questions. *Retweetrank.* URL: http://www.retweetrank.com/view/faq

Rjad, J. K., Norris, F. H., & Ruback, R. B. (1999). Predicting evacuation in two major disasters: risk perception, social influence, and access to Resources1.*Journal of Applied Social Psychology*, *29*(5), 918-934. doi: 10.1111/j.1559-1816.1999.tb00132.x

Rogers, E. (2010). *Diffusion of innovations*. (4th Ed.). Simon and Schuster, New York.

Rothenberg, R. (1995). Commentary: sampling in social networks. *Connections, 18(1).* 104-110. URL: http://bit.ly/1O2v8JF

Ryo. (2011). 17 most tweeted events of 2011. *Skeptikai*. URL: http://bit.ly/1Q3eUhs

Sakaki, T., Okazaki, M., & Matsuo, Y. (2010). Earthquake shakes Twitter users: real-time event detection by social sensors. In *Proceedings of the 19th international conference on World wide web*, 851-860. doi: 10.1145/1772690.1772777

Scheufele, D. A., & Tewksbury, D. (2007). Framing, agenda setting, and priming: The evolution of three media effects models. *Journal of communication*, *57*(1), 9-20. doi: 10.1111/j.0021-9916.2007.00326.x

Scott, J. (2013). *Social network analysis*. Sage Publications, London: United Kingdom.

Sharp, K. M., & Losavio, K. (2011). Interoperability & Other Lessons Learned from 9/11. *Public Safety Communications*. URL: http://bit.ly/1IZ6GRI

Slovic, P., Peters, E., Finucane, M. L., & MacGregor, D. G. (2005). Affect, risk, and decision making. *Health Psychology, 24*, 35-40. doi: 10.1037/0278-6133.24.4.S35

Smith, N. (2006). There's no such thing as a natural disaster. In *Understanding Katrina: Perspectives from the Social Sciences.* SSRC. URL: http://bit.ly/1yMEh2b

Sohn, D. (2009). Disentangling the effects of social network density on electronic word-of-mouth (eWOM) intention. *Journal of Computer‐Mediated Communication*, *14*(2), 352-367. doi: 10.1111/j.1083-6101.2009.01444.x

Spiro, E. S., Fitzhugh, S., Sutton, J., Pierski, N., Greczek, M., & Butts, C. T. (2012). Rumoring during extreme events: A case study of Deepwater Horizon 2010. In *Proceedings of the 3rd Annual ACM Web Science Conference*, 275-283. doi: 10.1145/2380718.2380754

Stanchak, J. (2010, February 2). Live from Social Media Week: How Twitter saved lives in Haiti. *Smart Blog on Social Media.* URL: http://bit.ly/1Qpxb8G

Starbird, K., Palen, L., Hughes, A. L., & Vieweg, S. (2010). Chatter on the red: what hazards threat reveals about the social life of microblogged information. In *Proceedings of the 2010 ACM conference on Computer supported cooperative work,* 241-250. ACM. doi: 10.1145/1718918.1718965

Starbird, K., & Palen, L. (2010). *Pass it on?: Retweeting in mass emergency*. International Community on Information Systems for Crisis Response and Management. URL: http://bit.ly/1VOPUhj

Starbird, K., Palen, L., Hughes, A. L., & Vieweg, S. (2010, February). Chatter on the red: what hazards threat reveals about the social life of microblogged information. In *Proceedings of the 2010 ACM conference on Computer supported cooperative work,* 241-250. ACM. doi: 10.1145/1718918.1718965

Starbird, K., & Stamberger, J. (2010). Tweak the tweet: Leveraging microblogging proliferation with a prescriptive syntax to support citizen reporting. In *Proceedings of the 7th International ISCRAM Conference*. Seattle, WA. URL: http://bit.ly/1EPlUhi

Starbird, K., & Palen, L. (2011). Voluntweeters: Self-organizing by digital volunteers in times of crisis. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 1071-1080. doi: 10.1145/1978942.1979102

Starbird, K., Muzny, G., & Palen, L. (2012). Learning from the crowd: Collaborative filtering techniques for identifying on-the-ground Twitterers during mass disruptions. In *Proceedings of the 9th International Conference of Information Systems in Crisis Response Management ISCRAM*. URL: http://bit.ly/1hZpgDI

Stephansen, H. C., & Couldry, N. (2014). Understanding micro-processes of community building and mutual learning on Twitter: a ‘small data’ approach. *Information, Communication & Society*, *17*(10), 1212-1227. doi: 10.1080/1369118X.2014.902984

Sutton, J., Palen, L., & Shklovski, I. (2008). Backchannels on the front lines: Emergent uses of social media in the 2007 southern California wildfires. In *Proc. 5th Int. ISCRAM Conference,* 624-632. Washington, DC. URL: http://bit.ly/1FyL5PR

Sutton, J. (2010). Twittering Tennessee: Distributed Networks and Collaboration Following a Technological Disaster. In *Proceedings of the 7th International ISCRAM Conference–Seattle*. URL: http://bit.ly/1OecdLd

Sutton, J., Spiro, E., Johnson, B., Fitzhugh, S., Gibson, B. & Butts, C. (2014). Warning tweets: serial transmission of messages during the warning phase of a disaster event. *Information, Communication & Society, 17:6,* 765-787. doi: 10.1080/1369118X.2013.862561

Sysomos (2014). Inside Twitter: an in-depth look inside the Twitter world. *Sysomos.* URL: http://sysomos.com/uploads/Inside-Twitter-BySysomos.pdf

Taubenböck, H., Goseberg, N., Setiadi, N., Lämmel, G., Moder, F., Oczipka, M., et. al, (2009). " Last-Mile" preparation for a potential disaster–Interdisciplinary approach towards tsunami early warning and an evacuation information system for the coastal city of Padang, Indonesia. *Natural Hazards and Earth System Science*, *9*, 1509-1528. URL: http://bit.ly/1gaGUDa

TweetReach (2014). About TweetReach. *TweetReach.* URL: http://bit.ly/1LleMG5

Timoney, K. P., & Lee, P. (2009). Does the Alberta tar sands industry pollute? The scientific evidence. *Open Conservation Biology Journal,* 3, 65-81. doi: 1874-8392/09

United Nations. (2004). Living with risk: A global review of disaster reduction initiatives. *International Strategy for Disaster Risk Reduction*. Geneva. URL: http://bit.ly/1Mi5Inf

United Nations (2008). Linking disaster risk reduction and poverty reduction: Good practices and lessons learned. *International Strategy for Disaster Risk Reduction.* URL: http://bit.ly/1K9mnGN

United States Geological Survey (2012). Earthquakes with 50,000 or more deaths. URL: http://earthquake.usgs.gov/earthquakes/world/most_destructive.php 4

United Nations (2013). *Ocha Policy and Study Series: Humanitarianism in the Networked Age Including Data and Trends 2012.* URL: http://bit.ly/1F8Hywl

Vasterman, P., Yzermans, C., & Dirkzwager,A. (2005). The role of the media and media hypes in the aftermath of disasters. *Epidemiologic reviews, 27,* 107-114. doi: 10.1093/epirev/mxi002

Vieweg, S., Palen, L., Liu, S. B., Hughes, A. L., & Sutton, J. (2008). Collective intelligence in disaster: An examination of the phenomenon in the aftermath of the 2007 Virginia Tech shootings. In *Proceedings of the Information Systems for Crisis Response and Management Conference (ISCRAM)*. URL: http://bit.ly/1ieOqPb

Vieweg, S., Hughes, A., Starbird, K. and Palen, L. (2010) Microblogging during two natural hazards events: what Twitter may contribute to situational awareness. In *Proceedings of ACM Conference on Computer Human Interaction (CHI).* doi: 10.1145/1753326.1753486

Wahlberg, A., & Sjoberg, L. (2000). Risk perception and the media. *Journal of risk research, 3(1),* 31-50. doi: 10.1080/136698700376699

Watts, D. J., & Dodds, P. S. (2007). Influentials, networks, and public opinion formation. *Journal of consumer research*, *34*(4), 441-458. doi: http://dx.doi.org/10.1086/518527

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications* (Vol. 8). Cambridge University Press, Cambridge: United Kingdom.

World Economic Forum (2014). Global risks 2014. (9th Ed.). *The World Economic Forum.* URL: http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2014.pdf

# Appendix A. Opinion Leader Survey

**Website Script:**

*You are invited to participate in a survey about Twitter and tsunami risk communication. My name is Amanda Oldring, and this survey is part of my Master of Arts thesis in Communication at Simon Fraser University (SFU). I have contacted you because your Twitter account followed @NWS_NTWC, the official account for the US National Weather Service's National Tsunami Warning Centre. This account administers alerts and warning information to most of North America's Pacific coastal regions. Your account may also be an opinion leader capable of influencing the opinions and behaviors of other people in Twitter. The goal of this study is to learn about your perceptions of and opinions about using Twitter to communicate risk and tsunami hazard information. Your responses are highly valued. They will be kept confidential and will help further our understanding of how communication networks form in Twitter prior to the onset of a disaster.*

*The survey is securely hosted on SFU's Web Survey platform. It has 39 questions, and should take 10-15 minutes to complete. Please read the informed consent form carefully. If you have any questions, or prefer to take the survey via phone or Skype, see the Contact page. At the end of the survey, you will be asked to submit your responses. If you select "No", your responses will not be saved. When you are ready, click the link below to start.*

**Recruitment Tweets:**

Request: *Hi, I am an SFU MA student researching Twitter & tsunami communication. Would you like to participate in a short survey?*

Accept: *Thank you :) The details & survey are at www.sfu.ca/~aoldring/tsunamiproject - please DM me for any questions/discussion. I appreciate your time!*

Decline: *Thank you for your time.*

Completed: *Thanks so much for your time and interest! If you opted for feedback I will be in touch again when the study ends. :)*

**Informed Consent Form:**

You are being invited to take part in a research study on social media and tsunami risk and early warning communication. If you would like to participate, you will be given a brief survey about your day-to-day use of Twitter, and your opinions about using Twitter for risk communication. You have been selected because your Twitter account is likely to be influential, indicates a location either in British Columbia (Canada), or in Alaska, Washington, Oregon, or California (US), and follows the US's National Tsunami Warning Centre's account, @NWS_NTWC. This research is part of a thesis required for my Master of Arts degree in Communication. It has been approved by Simon Fraser University and the University's Research Ethics Board.

*External Funding*: The study is funded in part by the Emergency Preparedness Conference Scholarship in Emergency Communications.

*Research Team*: Principal Investigator: Amanda Oldring, School of Communication, Simon Fraser University. (P: [...]. E: […]@sfu.ca ). Faculty Supervisor: Dr. Peter Anderson, School of Communication, Simon Fraser University. (P: […] E: […]@sfu.ca )

*About the Study*: We want to learn how tsunami early warning and risk communication networks are formed in Twitter. Our study focuses on people who follow @NWS_NTWC and who live or work near the west coasts of Canada and the United States. We are especially interested in how influential people (opinion leaders) use Twitter. This study will help us learn the roles opinion leaders fill in Twitter prior to a tsunami event. We want to study their reasons for following @NWS_NTWC, how they use Twitter and other systems to learn about and communicate risk, and what they think Twitter's strengths and limitations are for tsunami early warning systems. The study's aim is to map the geological and social networks of west coast tsunami risk communicators for the purposes of better understanding regional differences between Canada and the United States. We are inviting people like you, the opinion leaders in the @NWS_NTWC's network, to help us.

*Participation is Voluntary*: You have the right to refuse to participate in this study at any time and without any negative consequences. If you decide to participate and then wish to withdraw during the course of the study, simply exit the survey without submitting it and your responses will not be saved. In the event that you decline to participate, any data collected about you during the course of the study will be destroyed.

*Procedure*: If you click "Yes" to Question 1 at the bottom of this document, you will be directed to a survey on tsunami risk communication and Twitter use. There are three required fields: 1) your Twitter username, to verify you are a follower of @NWS_NTWC, 2) your primary location, to verify you are part of the coastal regions of interest to this study, and 3) your declaration that you are 19 years of age or older and fluent in English to verify your eligibility. The rest of the questions are about your experience and opinion of communicating tsunami risk in Twitter. These questions are optional and you do not have to answer if you do not want to. Surveys will be administered between August 1 and August 31, 2014. You may be sent a follow-up reminder if your survey is not completed in time. Incomplete surveys will be not be used. The survey should take no more than 10-15 minutes to complete. Please take your time, and take breaks if needed. If you prefer to conduct the survey by phone/Skype you may. Please inform the researcher.

Survey responses will be stored on a password secured Canadian server. All study materials will be destroyed two years after the completion date of August 31, 2014. Your directly identifying information will not be disclosed in the study. Your responses will be kept anonymous, although you may be indirectly referred to by your Twitter account's role in the @NWS_NTWC network (i.e. media, government, private sector) and by 'fuzzy' (non-coordinate) location or region (i.e. Vancouver, BC, Vancouver Island).

*Potential Risks*: This study has been designated as minimal risk. There are no significant risks to you in participating in this study. Please note that your Twitter account is public, so there is a very small chance it could be identified despite our precautions.

*Potential Benefits*: This study may or may not benefit you. The results will be used to make recommendations for tsunami early warning systems in Canada, and to help separate the myths and realities of using Twitter for emergency communications, which may be of direct or indirect benefit to you.

*Payment*: We are unable to pay you for your participation in this study.

*Confidentiality*: Your anonymity and confidentiality will be respected. Please note that your anonymity cannot be guaranteed if you disclose personal information publically on Twitter, such as your name or address. Similarly, your confidentiality cannot be guaranteed because we are collecting data over the Internet, and there is always a small risk that this information can be intercepted by third-parties. Information that discloses your identity will not be released without your consent unless required by law. Electronic files will be password protected on a Canadian-secured server. Hard copies will be locked in a filing cabinet in the Principal Investigator's (secured) home. There is no known future use of the data beyond the conclusion of the research project.

*Return of Results*: The results of this study will be reported in a graduate thesis and may also be published in journal articles and books. Main findings may also be presented at academic conferences. If you wish to receive email feedback on the study's results, please provide an email address in Question 3 or inform the researcher.

*Contact*: Any inquiries about the study will be answered to ensure that you fully understand them. If you have any questions or feedback about the study you may contact the researcher, Amanda Oldring (see Research Team). If you would like to provide anonymous feedback about the study, you may contact the Faculty Supervisor, Peter Anderson (see Research Team). If you have any concerns about your rights as a research participant and/or your experiences while participating in this study, you may contact: Dr. Dina Shafey, Associate Director, Office of Research Ethics (P: […]. E: […]@sfu.ca ).

### Survey Questions

**Yes/No:** By clicking "Yes" to this question, I agree that I have read the declaration of informed consent presented above, and agree to participate in this research. I recognize that I am free to retract my participation at any time and for any reason with no repercussions, and that if I do so any data I provide will not be used. I verify that I understand the study's purpose, procedure, benefits, and risks, what my role is, and how my information will be used. I confirm that I have been given ample opportunity to ask questions and to clarify the study's scope prior to and during the survey, and that I have been given the opportunity to give and receive feedback on the results.

1. **Yes/No:** Are you 19 years of age or older and fluent in English?
2. **Text:** Would you like to receive feedback about the study results? If so, please provide your email address so that we can reach you. Otherwise, leave this question blank.
3. **Single Line of Text:** For authentication reasons, please provide the Twitter username that you use to follow @NWS_NTWC.
4. **Single Choice:** Please specify the primary purpose of your Twitter account. **Options:** Work, Personal, Academic Study or Research, Other.

5. **Single Line of Text:** If you selected "Other", please specify.
6. **Single Choice:** Do you live in one of the following provinces or states? If so, please select the one that applies. **Options:** British Columbia, CAN; Alaska, USA; California, USA; Oregon, USA; Washington, USA; Other.
7. **Single Line of Text:** If you selected "Other", please specify.
8. **Single Line of Text:** What city/town do you currently work or reside in?
9. **Yes/No:** Is your primary place of work or residence in a coastal community near the Pacific Ocean?
10. **Single Choice:** What is the top reason why you follow @NWS_NTWC? **Options:**
    a. To track tsunami notifications, alerts, and warnings for my immediate area or my friend's and loved one's immediate areas.
    b. To collect news about tsunamis anywhere in the Pacific Ocean.
    c. To communicate tsunami information to others I personally know and who may be impacted.
    d. To communicate tsunami information to the public.
    e. All of the above
    f. Other
11. **Single Line of Text:** What city/town do you currently work or reside in?
12. **Single Choice:** How often do you pay attention to information from @NWS_NTWC? **Options:** Never, Rarely, Sometimes, Often, All the time.
13. **Multiple Choice:** Do you work or volunteer in any of the following disaster management areas? Please select all that apply. **Options:**
    a. Traditional Media (i.e. News, TV, Radio (including electronic versions of these such as digital radio)
    b. Social Media (i.e. Twitter, Facebook, Instagram)
    c. Non-Profit, NGO, or Public Sector (i.e. Red Cross)
    d. First Response (i.e. Search and Rescue, Police, Fire, Paramedic)
    e. Government (i.e Civil Service)
    f. Technical Sciences (i.e. Meteorology, Seismology, Hydrology)
    g. Hobbyist (i.e. HAM Radio, amateur meteorologist)
    h. Private Sector (i.e. emergency consulting, products or services, private security, safety and risk services)
    i. Other disaster related field
    j. None
14. **Single Line of Text:** If you selected "Other", please specify.
15. **Multiple Choice:** In your opinion, in what ways could Twitter most benefit tsunami or other coastal hazard emergency response? (Please select all that apply). **Options:**
    a. Early warning system
    b. Real-time mass notification system
    c. Real-time local communication system
    d. Monitoring system for providing regular watches and advisory updates
    e. Public, private, or local authority coordination
    f. Interoperability (coordination) between public, private, and emergency management groups
    g. Situational awareness (providing visibility into real-time events as they unfold)
    h. "Last-Mile" (hard to reach) population access
    i. Rumor or miscommunication prevention
    j. Fundraising
    k. Social support (i.e. sharing stories, grieving, coping)

l. Solicit or provide aid
m. Other
n. None

16. **Single Line of Text:** If you selected "Other", please specify.
17. **Multiple Choice:** In your opinion, in what ways could Twitter most benefit disaster management outside of an actual tsunami or other coastal hazard event? (Select all that apply). **Options:**
    a. Providing public safety information
    b. Increasing disaster management followers
    c. Building cooperative relationships with followers
    d. Providing disaster prevention/mitigation information
    e. Providing disaster preparation information
    f. Increasing hazard and risk awareness
    g. Identifying at-risk populations
    h. Other
    i. None
18. **Single Line of Text:** If you selected "Other", please specify.
19. **Multiple Choice:** In your opinion, what are the biggest limitations to using Twitter for tsunami or coastal hazard communication? Please select all that apply. **Options:**
    a. Messages are too short.
    b. Messages might not reach the intended recipients.
    c. Anyone can see a message.
    d. Anyone can contribute messages.
    e. Messages might not be formally authorized by an emergency service provider.
    f. Users could exploit disaster events to increase their popularity on Twitter.
    g. Users could spread misinformation or rumours that are difficult to clear up quickly.
    h. Emergency managers cannot control who participates in hazard communication.
    i. Other
    j. None
20. **Single Line of Text:** If you selected "Other", please specify.
21. **Single Choice:** Approximately how many hours per week do you spend viewing or using Twitter? **Options:** Less than 1, 1 – 5, 6 – 10, 11 – 15, 16 – 20, 21 or more.
22. **Single Choice:** On an average day, how much of your time on Twitter is spent tweeting about disasters, hazards, or risk information, including information about the weather? **Options:** All of it (100%), Most of it (~75%), Half of it (~50%), Some of it (~25%), Hardly any (less than 25%), None (0%).
23. **Single Choice:** On an average day, how much of your time on Twitter is spent interacting with (replying to, retweeting, or direct messaging) other users? **Options:** All of it (100%), Most of it (~75%), Half of it (~50%), Some of it (~25%), Hardly any (less than 25%), None (0%).
24. **Single Choice:** How many of those interactions pertain to disasters, hazards, risks, emergency management, or the weather? **Options:** All of them (100%), Most of them (~75%), Half of them (~50%), Some of them (~25%), Hardly any (less than 25%), None (0%).
25. **Single Choice:** On an average day, how much time of your time on Twitter is spent reading or viewing content from other Twitter users? **Options:** All of it (100%), Most

of it (~75%), Half of it (~50%), Some of it (~25%), Hardly any (less than 25%), None (0%).

26. **Single Choice:** How much of the content that you view is related to disasters, hazards, risks, emergency management, or the weather? **Options:** All of it (100%), Most of it (~75%), Half of it (~50%), Some of it (~25%), Hardly any (less than 25%), None (0%).
27. **Single Choice:** How important is Twitter to tsunami or coastal hazard emergency management systems? **Options:** 1 – Not important, 2 – A little important, 3 – Somewhat important, 4 – Important, 5 – Extremely Important.
28. **Single Choice:** Rate the accuracy of the following statement: I am highly aware of natural hazards in my environment. **Options:** 1 – Inaccurate, 2 – Somewhat Inaccurate, 3 – Equally accurate and inaccurate, 4 – Somewhat accurate, 5 – Accurate.
29. **Single Choice:** Rate the accuracy of the following statement: I consider myself well informed on my coastal area's particular earthquake and tsunami risks. **Options:** 1 – Inaccurate, 2 – Somewhat Inaccurate, 3 – Equally accurate and inaccurate, 4 – Somewhat accurate, 5 – Accurate.
30. **Single Choice:** Rate the accuracy of the following statement: I am able to influence the behaviour of my Twitter account's followers. **Options:** 1-Inaccurate, 2-Somewhat Inaccurate, 3-Equally accurate and inaccurate, 4-Somewhat accurate, 5-Accurate.
31. **Multiple Choice:** Do you have access to other sources for tsunami warning information? Please select all that apply. **Options:**
    a. Other Twitter accounts
    b. Email distribution lists
    c. Websites (including Forums)
    d. Other social media (i.e. Facebook)
    e. Text messaging subscription services
    f. Traditional media, including electronic versions (i.e. newspapers, television, radio)
    g. A physical warning system (i.e. community sirens, door to door notifications)
    h. Other
    i. I do not have access to other tsunami warning information systems.
32. **Single Line of Text:** If you selected "Other", please specify.
33. **Single Choice:** In your opinion, which kind of hashtag is more effective for communicating disaster information? **Options:**
    a. Formal hashtags developed by emergency managers before a disaster
    b. Informal hashtags developed in Twitter by users in response to a disaster
    c. Both
    d. Neither
    e. None
34. **Multiple Lines of Text:** Please explain why you chose this answer.
35. **Single Choice:** In your opinion, is it better to… **Options:**
    a. Let emergency managers control tsunami information
    b. Allow the public to inform emergency managers about tsunami information
    c. Both
    d. Neither
36. **Multiple Lines of Text:** Please explain why you chose this answer.
37. **Multiple Lines of Text:** Lastly, do you have any suggestions for ways that Twitter communication for tsunamis or coastal hazards can be improved?

38. **Yes/No:** Thank you for completing this survey. Would you like to submit your responses?