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Why did Rikuzentakata have a high death toll in the 2011 Great East Japan Earthquake and Tsunami disaster? Finding the devastating disaster's root causes

Tadashi Nakasu[a,*], Yuichi Ono[b], Wiraporn Pothisiri[a]

[a] College of Population Studies, Chulalongkorn University, Visid Prachuabmoh Building, Bangkok 10330, Thailand
[b] International Research Institute of Disaster Science (IRIDeS), Tohoku University, Sendai, Miyagi 980-0845, Japan

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ABSTRACT

This paper aims to identify the root causes that exacerbated the loss of life from the 2011 Great East Japan Earthquake and Tsunami (GEJET) disaster in one of the local municipalities, Rikuzentakata. Finding root causes is crucial for learning from disasters; however, there has not been much investigation of the root causes with regard to the GEJET disaster. This paper seeks to investigate systematically the root causes of the loss of life by organizing the existing analytical frameworks, tools and approaches in order to clarify why Rikuzentakata experienced such a high death toll. The study's research design includes a social background survey, an in-depth interview survey and an investigation of the disaster's root causes. Through the research design, inappropriate regional development and urbanization, inadequate tsunami countermeasures in the area and misguided belief systems based on aged memories of the local people have been identified as root causes for the high death toll in Rikuzentakata. This study also provides four key points essential to building resilient communities: 1) education and training to consider local people's misguided belief system using their own memories and excess reliance on infrastructure and warning systems; 2) land-use considerations regarding regional development and urbanization; 3) learning lessons from previous disaster risk-management efforts to confirm tsunami countermeasures in the area; and 4) countermeasures for the elderly to harmonize with an aging society.

1. Introduction: research objectives and structures

The 2011 Great East Japan Earthquake and Tsunami (GEJET) struck communities along the northeastern coastline of Japan's Iwate, Miyagi and Fukushima prefectures. The magnitude 9.0 earthquake produced huge tsunamis and wreaked destruction along the Tohoku coast of Japan [1]. It was the largest magnitude earthquake ever recorded in Japan, and the Japan's deadliest disaster after the Second World War, which left 15,894 people dead and 2561 people missing [2]. The high-water level of 40.1 m at Ryouri Bay on the Sanriku ria coast in Iwate prefecture was the highest tsunami ever measured in the country [3].

The purpose of this research is to identify the root causes that exacerbated the loss of human life in the city of Rikuzentakata in Iwate prefecture – one of the local coastal municipalities most devastated by the 2011 GEJET disaster. Finding root causes is critical to learning from disasters. However, it has been difficult to identify the best ways to investigate the root causes of the GEJET disaster. Therefore, this paper seeks to investigate the root causes systematically by identifying target areas and organizing existing analytical frameworks in order to clarify why Rikuzentakata experienced a high death toll in the GEJET disaster as follows:

- The paper first describes the impact of the GEJET disaster relative to those of previous major tsunamis, explaining why the study focuses on Rikuzentakata city.
- Second, the paper examines research methodologies to identify root causes of disasters. A social background survey, in-depth interview survey and disaster root-cause investigation methodologies are employed to clarify how the root causes of the GEJET disaster have been identified in Rikuzentakata.

Abbreviations list: CDH, Completely Destroyed House; CRT, Current Reality Tree; DR/IA, Death Rates in the Inundated Area; FDMA, Fire and Disaster Management Agency; FORIN, Forensic Investigations of Disasters; GEJET, Great East Japan Earthquake and Tsunami; GIS, Geographic Information System; HVI, Human Vulnerability Index; ICHARM, International Center for Water Hazards and Risk Management; IRDR, Integrated Research on Disaster Risk; JMA, Japan Meteorological Agency; MIC, Ministry of International Affairs and Communication; MLIT, Ministry of Land, Infrastructure, Transportation, and Tourism; RA, Reconstruction Agency; UNISDR, United Nations Office for Disaster Risk Reduction

* Corresponding author.
E-mail address: Tadashi.N@chula.ac.th (T. Nakasu).

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– Third, the paper investigates published research findings and detects root causes that have been identified using the above three methodologies.
– Finally, the paper summarizes the lessons learned from this case study and highlights four key points essential to building resilient communities.

2. Why the study focuses on Rikuzentakata on the Sanriku ria coast

This study focuses on Rikuzentakata on the Sanriku ria coast, one of the municipalities most devastated by the 2011 GEJET disaster.

2.1. High death rates in inundated areas

The paper begins by comparing the death rates of the municipalities affected by the GEJET disaster on both the Sanriku ria and flat coasts owing to geographical and historical differences. Death rate means dead and missing caused by the GEJET disaster divided by the total population of the municipalities. Then, the paper examines the death rates in the inundated areas (DR/IA) of each municipality because DR/IA are indicative of the actual severity of the impact of a tsunami. Using only death tolls or the number of houses that collapsed is not adequate to compare the relative impact on the different communities since these numbers are influenced by various hazards such as tsunami heights and geographical locations. Using the death rate in a community is also inadequate, because each community has a different geography and population size.

Table 1 provides an overview of the impact of the GEJET disaster by geographical landform. Table 2 summarizes the impact of the GEJET disaster for each municipality in different geographical landforms in Iwate, Miyagi, and Fukushima prefectures. The dead and missing data calculation was based on the overall number of dead and missing provided by the Fire and Disaster Management Agency (FDMA) [4], reduced by disaster-related death numbers provided by the Reconstruction Agency (RA) [5]. Data for the completely destroyed houses (CDHs) was also taken from FDMA. Data related to the inundated area was provided by Geospatial Information Authority of Japan [6]. The population in the inundated area was taken from Statistic Office, Ministry of Internal Affairs and Communication [7]. Tsunami height data was delivered by Ministry of Land, Infrastructure, Transportation and Tourism (MLIT) [8]. Population data for each municipality was taken from Census, Japan, 2010 [9].

The average DR/IA along the Sanriku ria coast was 4.55% – much higher than that which occurred along the flat coast in Miyagi and Fukushima prefectures, as shown in Tables 1 and 2. The Sanriku ria coast extends from Kuji in the northern part of Iwate prefecture, to Onagawa in the Ojika peninsula in Miyagi prefecture. The flat coast referenced in this paper extends from Ishinomaki to Minamisoma in Fukushima prefecture, as shown in Fig. 1. The flat coast includes Matsushima Bay, which consists of approximately 260 small islands [10]. It is estimated that this natural condition reduced the damage from the tsunami since the small islands acted as natural barriers [11]. The coast also includes Ishonomaki city which has a ria part. The Sanriku ria coast suffered severe damage from the GEJET disaster and has also been impacted in the past by major tsunamis. Areas along the flat coast have not been affected by tsunamis as repeatedly [12].

Table 1
Overview of the GEJET disaster's impacts by coastal landform (Updated March 20, 2016). *Source:* [2,4–9].

	Sanriku Ria Coast	Flat Coast
Dead or Missing	8783	9055
Completely-Destroyed Houses (CDHs)	33,988	70,811
Inundated Areas (IAs) (Km^2)	87	375
Population in IAs	167,538	297,613
Average DR/IA	4.55%	2.80%
Average Death Rate	2.9%	1.0%
Average CDH Rate	29.6%	14.1%
Tsunami Height	5–20 m	3–15 m
Population	357,155	1724,571

Table 2
The GEJET disaster's impacts along the Sanriku Ria and Flat Coasts (Updated March 20, 2016).

Sanriku Ria Coast	Dead or Missing	Inundated Areas (IAs) (km^2)	Death Rates	Death Rates in IA (dr/ia)
Kuji	5	4	0.01%	0.07%
Noda	38	2	0.82%	1.20%
Fudai	1	1	0.03%	0.09%
Tanohata	29	1	0.75%	1.83%
Iwaizumi	7	1	0.06%	0.62%
Miyako	514	10	0.86%	2.80%
Yamada	752	5	4.04%	6.59%
Otsuchi	1229	4	8.05%	10.31%
Kamaishi	1039	7	2.63%	7.89%
Ofunato	419	8	1.03%	2.20%
Rikuzentakata	1763	13	7.57%	10.59%
Kesennuma	1325	18	1.80%	3.29%
Minamisanriku	812	10	4.66%	5.64%
Onagawa	850	3	8.46%	10.56%
Total / Average	8783	87	2.91%	4.55%

Flat Coast *Matsushima Bay	Dead-Missing Number	Inundated Area (IA) (km^2)	Death Rate	Death Rates in IA (dr/ia)
Ishinomaki	3705	73	2.30%	3.30%
Higashimatsushima*	1086	37	2.53%	3.19%
Matsushima*	2	2	0.01%	0.05%
Rifu*	1	0.5	0.00%	0.18%
Shiogama*	24	6	0.04%	0.13%
Shichigahama*	78	5	0.38%	0.85%
Tagajo	188	6	0.30%	1.10%
Sendai	681	52	0.07%	2.27%
Natori	949	27	1.30%	7.81%
Iwanuma	181	29	0.41%	2.25%
Watari	270	35	0.77%	1.92%
Yamada	698	24	4.18%	7.76%
Shinchi	99	11	1.20%	2.12%
Souma	456	29	1.21%	4.37%
Minami Souma	637	39	0.90%	4.76%
Total/Average	9055	375.5	1.04%	2.80%

As summarized in Table 1, municipalities on the flat coast experienced high death tolls and completely destroyed houses (CDHs) during GEJET, as well as huge inundated areas (IAs) that included highly populated areas; however, the average death rate, average CDH rate and average DR/IA from GEJET were not as high as those on the Sanriku ria coast. In comparison, the municipalities of Otsuchi, Kamaishi and Rikuzentakata on the Sanriku ria coast were extremely hard-hit by the GEJET disaster, as shown by the death tolls summarized in Table 2: Kamaishi, 1038; Otsuchi, 1229; Kesennuma, 1325; and Rikuzentakata, 1765. Of these, Rikuzentakata appears to have had the highest death toll on Sanriku ria coast.

Otsuchi and Rikuzentakata both had high death rates. Otsuchi's death rate (8.05%) was higher than Rikuzentakata's (7.59%); however, Rikuzentakata's DR/IA (10.59%) was higher than Otsuchi's (10.31%). Kamaishi had a high death toll (1039), however, a low death rate (2.63%) and not as high a DR/IA (7.89%). These variances can be attributed to differences in geographies and population sizes, as well as the direct impact of the tsunami. Rikuzentakata had the highest death toll along the Sanriku ria coast and the highest DR/IA from the GEJET disaster.

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