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FEATURES OF TSUNAMI EVACUATION OF ORGANIZATIONS AND INDIVIDUALS AT THE GREAT EAST JAPAN EARTHQUAKE TSUNAMI

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Abstract

The residents of Kadowaki-cho, Minamihama-cho, and Hibarino-cho in the southwestern part of Ishinomaki-city, Miyagi Prefecture, suffered much human damage from the tsunami caused by the Great East Japan Earthquake of March 11, 2011. The fatality rate of local residents was higher than that of organization personnel of public and business establishments scattered through the area. There was observed to be large differences between the evacuation behavior of organization personnel who were working in the area at the time of the earthquake and that of local individual residents. Organization personnel evacuated in an orderly manner, whereas around 30% of local residents, did not evacuate and others evacuated but in a disorderly manner. Some evacuating residents even turned back home before the tsunami arrived and were then washed away.

The author studied the difference between these evacuation behaviors via interview and questionnaire surveys. The following facts became clear: At many organizations, the person in charge obtained information from organization staff and quickly made a clear decision to evacuate toward a nearby hill, and other personnel evacuated in much the same manner as per their training. Many of these organizations were aware of the tsunami risk beforehand, and prepared an evacuation plan and trained their employees for evacuation. However, the Ishinomaki City Office designated most of this area as not being a tsunami inundation area on its published hazard map. Drills for tsunami evacuation were not implemented in this area, and hence residents were not wary of a tsunami. Some stayed in their houses without thinking of a tsunami or were waiting for family to return. Some had to care for bedridden family members. There seemed to be no powerful community leaders in the area to let people evacuate. Moreover, residents had no way to specifically know about the approach of the large tsunami besides the fragmentary information via radio.

Keywords: tsunami evacuation, Great East Japan Earthquake, organization personnel and individual residents

1. Introduction

Fig.1 shows the location of Ishinomaki, and Fig.2 shows the location of the survey area (2-5 Kadowaki-cho, 1-4 Minamiham-cho, and Hibarino-cho). The study area is a rectangular flat lowland of 1.3km x 0.8km bounded by sea, hill, river and a large paper mill. The closed up map is also shown in Fig.6 later. Light industrial facilities, a large hospital, a cultural facility and temples are scattered among residential houses, and the area has a population of 4,433 (2010 census). The tsunami in this area caused by the East Japan Great Earthquake on March 11, 2011 was about 6 m high, and most wooden houses (mainly two stories) in the area were washed away. There were 487 fatalities and missing (11.0% mortality).

The author organized a volunteer survey group [1], "Joint Survey Group on the Evacuation from the Great East Japan Earthquake Tsunami – Team for Ishinomaki survey (hereafter, Team for Ishinomai survey)" and interviewed 356 people who evacuated from the stricken area of Ishinomaki (hereafter, interview survey), and also distributed a questionnaire sheet to 3,300 families in temporary houses asking for answers be sent by mail (hereafter, posting survey). The recovery rate was 24%.

Fig.1 – Location of Ishinomaki and Onagawa

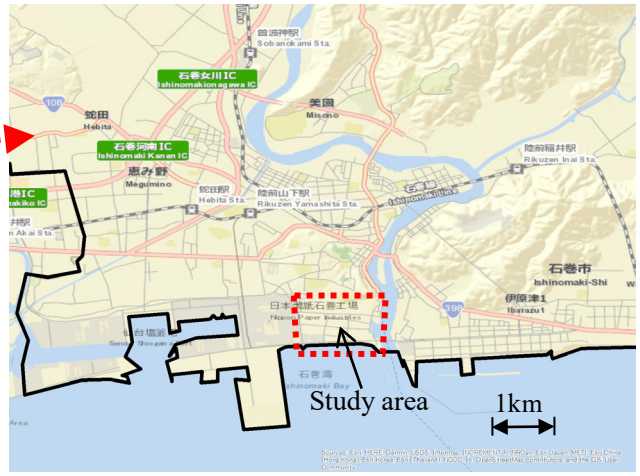


Fig.2 – Location of study area

The author also contacted six public and business organizations in the area and conducted interviews with representatives or got information about their performance. Some of these results have already been reported in Japanese [2], but this paper includes new findings and insights.

2. Earthquake, Tsunami Inundation, Information Transmission and Hazard Map

2.1 Earthquake shaking and its effects

According to the strong motion acceleration recorded at the K-net Ishinomaki station (MYG010, about 2 km west of the study area), two large shakings occurred about 40 seconds apart and continued for about 200 seconds in total. The maximum acceleration exceeded 400 gal.

The seismic intensity meters near the study area recorded the main shock as being 6-lower on the JMA intensity scale (approximately 9 on the MM seismic intensity scale). If we including JMA seismic intensity 1 level, 22 aftershocks occurred before the arrival of the tsunami (about 55 minutes) and people in the area felt almost continuous shaking. However, no building damage such as collapse was reported in the area. Although slight liquefaction occurred in some roads and some block walls fell down, car mobility was not hindered much.

2.2 Tsunami inundation

Fig.3 shows the tsunami inundation depth distribution of the study area drawn from data of the Earthquake Reconstruction Support Survey Archive [3] (hereafter, ERSS Archive). In the center of the area, the altitude was less than 1m and the inundation depth reached 5-7m. However, Hibarino, located on the shore side of Minamihama, was on a coastal dune and the altitude was slightly higher, so the inundation depth was shallow. Fig.4 shows a snapshot of Abe's simulation of a tsunami run-up on the study area [4]. Abe tuned the simulation parameters with GPS buoy data off Kinkazan and confirmed the suitability of the waveform with the observation data at Sendai New Port. It was thus estimated that the first tsunami reached the coast of the area 56 minutes after the earthquake's occurrence, and the maximum wave arrived about 60 minutes after.

2.3 Transmission of tsunami warning

The Ishinomaki Central Fire Department and the Ishinomaki City Disaster Prevention Division announced a tsunami alert and advised evacuation to hills 12 times before the tsunami arrived using outdoor loudspeakers of the disaster prevention administration radio system. However, according to the posting survey conducted by the Team for Ishinomaki survey, only 27% of responses of 111 persons who lived in the study area answered that they heard the alert and understood its meaning.

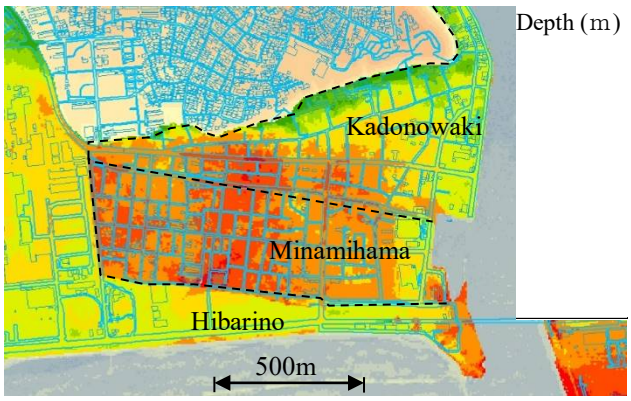


Fig.3 – Tsunami inundation depth drawn from ERSS Archive data

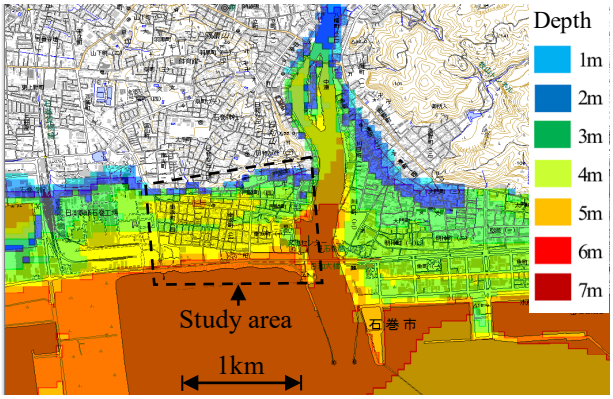


Fig.4 – Snap shot of tsunami inundation simulation courtesy of Ikuo Abe of Tokoha University

The Japan Meteorological Agency raised the expected tsunami height of its large tsunami warning from 6m to more than 10m (hereafter, revised tsunami height), 28 minutes after the earthquake (about 30 minutes before the tsunami hit the study area). Whether or not this information was transmitted promptly is one of the items that needs to be verified. Blackouts prevented most residents from watching TV, and many tried to get information from the radio. The author investigated the broadcasting situation of radio stations that could have been heard by Ishinomaki residents [5].

a) NHK, Japan's national broadcasting organization, broadcast the revised tsunami height by radio channel 46 minutes after the earthquake.

b) A major radio company in Miyagi prefecture did not broadcast the revised tsunami height, but broadcast in real time a large tsunami hitting Onagawa. Some residents heard this news.

c) FM raidio in Sendai broadcasted the revised tsunami height 35 minutes after the earthquake.

d) Community FM radio in Ishinomaki was unable to broadcast due to a trouble caused by the power outage.

The conclusion of this section is that many of the residents in the study area did not receive a clear warning that a large destructive tsunami was coming.

2.4 Hazard map

Ishinomaki City Office prepared a disaster prevention guide and hazard map booklet having several tens pages in A4 color printing, in March 2009 and distributed it to all houses. It included basic explanations, an evacuation site list, a disaster relief facilities list and hazard maps of flood risks, geological disaster, earthquake, tsunami and nuclear accident. A copy of the tsunami hazard map of the study area is shown in Fig.5. It did not indicate the possibility of tsunami inundation except for a part of Hibarino. It is obvious that the map greatly underestimated the tsunami inundation when it was compared with Fig.3 and Fig.4.

However, the awareness of residents of this booklet and the hazard maps was low. According to the posting survey, only 19% of respondents said they had seen and referred to this hazard map.

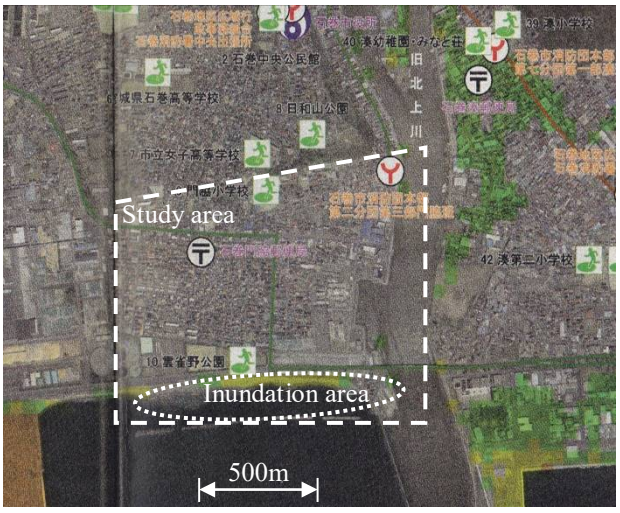


Fig.5 – Partial copy of hazard map published by Ishinomaki City Office

2.5 Traffic jams after the earthquake

According to many witnesses, it was estimated that the traffic on the west of the arterial road (see Fig.6) in this area began to congest from around 15:15 (29 minutes after the earthquake). The west exit of the arterial road was connected to the national road, which caused heavy traffic jams, and the traffic congestion going west on the arterial road seemed to originate there.

NHK recorded images of traffic coming and going on the Hiyori Bridge from after the earthquake until the tsunami hit using a telephoto camera installed on a hill (Hiyoriyama, see Fig.6). It could be seen that one car was moving into the study area approximately every 5 seconds. Assuming that all of this traffic flowed to the west on the arterial road and was completely stuck in one lane (The arterial road has one lane each way), a traffic jam of 1 km would occur in about 14 minutes. Therefore, it could be assumed that this influx vehicle affected the traffic congestion on the arterial road.

3. Evacuation of Organizations

The evacuation features of typical organizations shown in Fig.6 were investigated through interviews and references.

3.1 Kadowaki Elementary School

This school was designated as an evacuation site in the event of a tsunami, but was located in lowlands at an altitude of 3-4m. After the earthquake, teachers ordered students to immediately evacuate to a hill behind the school through a stairway nearby.

3.2 Kadowaki Nursery School

Isinomaki city Kadowaki Nursery School was almost in the center of the study area. Shortly after the earthquake, the director decided to evacuate to another nursery on a hill. This nursery school had

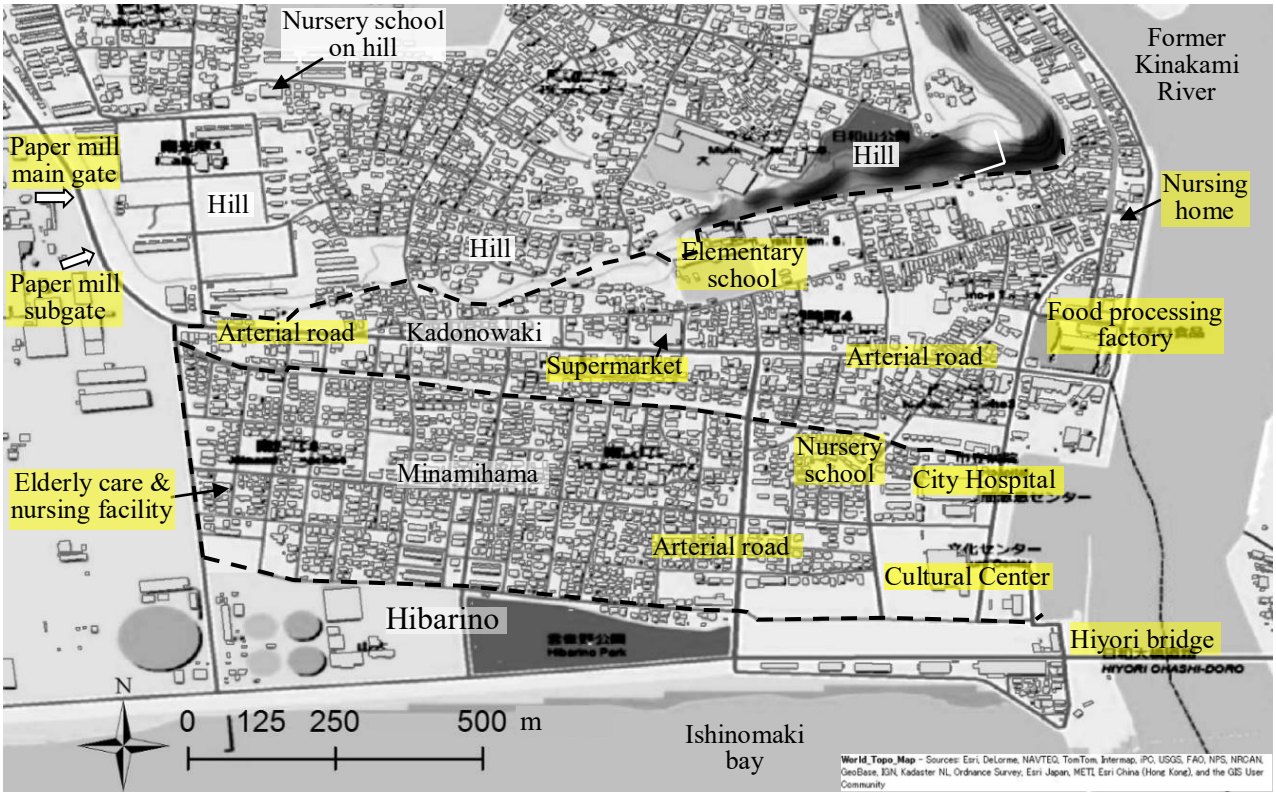


Fig.6 – Major organizations and hill of Kadonowaki, Minamihama and Hibarino areas

voluntarily conducted evacuation training once a month. After handing over some of the children to their parents, 20 children and 13 staff members departed at 15:15 with children under 1 year old piggybacked, 1-3 years old on wheelbarrows, 4 years old and older on foot. They walked about 2km to the destination nursery school and arrived at around 15:50 (5 minutes before the tsunami). Although the evacuation succeeded, there was no spare time.

3.3 Ishinomaki City Hospital

Ishinomaki City Hospital with 206 beds, was in the eastern part of the study area. Soon after the earthquake, its own power generator was started and information was obtained from TV. There were 66 people on the ground floor, and the hospital staff took them go up to the third floor. There were 153 hospitalized patients. 70-80 who had difficulty walking independently and disabled people who had evacuated from a nearby elderly care facility were taken to the third floor. It was very heavy work and one patient who helped others evacuate died.

3.4 Ishinomaki Cultural Center

The center was located on the east and sea sides of the study area. Visitors and part-time staff left before the tsunami arrived. Information about the large tsunami was given by a staff member who returned to the center from an outside meeting. Three female staff members attempted to evacuate by car, and one of them died in the tsunami during the evacuation. The other staff members evacuated to the upper floor and survived the tsunami. Historic cultural properties of Ishinomaki were stored in storage rooms on the ground floor, and all but a few were lost or severely damaged by the tsunami.

3.5 Large-scale paper mill

There was a large-scale paper mill in the west of the study area. At the time of the earthquake, 1307 employees were working there. Production activities were immediately suspended, and about 15 minutes after the earthquake, evacuation on foot or by bicycle started. The evacuation destination was a hill that could be reached within a few minutes of the factory's main gate. Due to the power outage, the security personnel obtained information from the city office and radio broadcasts and issued evacuation instructions using battery-powered indoor broadcasting equipment. Most evacuation had been completed by around 15:30. There were no tsunami casualties among employees who had been at work. The security personnel said that it was helpful to have reset the instruction manual based on the Chilean earthquake and tsunami of one year ago to achieve a thorough evacuation.

3.6 Food processing factory

There was a food processing factory in the eastern part of the study area where about 170 people were working when the earthquake occurred. Ten minutes after the quake, employees began to voluntarily go up to the rooftop of the two-story office building in accordance with an agreement with the factory. The plant manager got information about the tsunami from an employee who had obtained the information from the one-segment broadcasting service via his mobile phone, and determined that immediate evacuation was necessary. He instructed about 50 people who had already evacuated to the rooftop to stay there, and then ordered the remaining about 120 people to evacuate to a nearby hill on foot. Around 15 minutes after the earthquake, the remaining group evacuated while wearing white work clothes and were witnessed by residents in the vicinity. They played a role in pushing nearby residents to evacuate by showing their own evacuation. There were no tsunami casualties among employees who followed this evacuation instruction, but one of the employees returned her home to take care her family and died there.

3.7 Supermarket

There was a relatively large supermarket near the stairway up the hill from the study area. According to testimony recorded in the newspaper, the employees were instructed to return home or to evacuate to a hill after emergent shut down of the store. Another eyewitness said, after a large aftershock at 15:25, 10 to 15 supermarket personnel evacuated in a group toward a hill.

3.8 Elderly care and nursing facility

There were 47 elderly people and 30 staff members at the elderly care and nursing facility in the western part of the area at the time of the earthquake. As soon as the main shock subsided, the facility manager and staff decided to evacuate to an indoor practice place of the paper mill located on a hill about 300 meters away. A total of 87 people were evacuated, including 10 residents who had fled to the facility from the surrounding area. Motor transportation was provided for more than a dozen vehicles including pick-up wagons and staff cars. The evacuation was completed 30 minutes after the earthquake.

In the facility: (a) Evacuation drills had been practiced four times in 2010, assuming car evacuation. (b) One of the facility users who had experienced a tsunami was invited to give lectures several times so that staff and users could share awareness of tsunami. (c) Careful daily precautions were taken, for example, parking cars facing outward so that they could start quickly.

3.9 Nursing home

There was a nursing home near the river in the eastern part of the study area. After the main shaking had subsided, the administrator put the elderly residents in a microbus, but it took time for more than ten weak-leg persons to get in. The microbus headed to Kadowaki Elementary School, about 500m away and parked in the schoolyard. However, the tsunami arrived before the elderly persons could be removed from the microbus, and they died there. The driver and one of the staff were barely able to escape. The following three points are raised as the causes of this tragedy: (a) insufficient number of staff, (b) inappropriate transportation method. A microbus can carry many people at once, but it takes time to get on and off for elderly, (c) inappropriate choice of refuge place. Kadowaki Elementary School was in the danger area.

3.10 Summary of evacuation performance of organizations

The common features of successfully evacuated organizations are: (a) Evacuation destination was hill, (b) frequent drills had been done, (c) information were collected systematically, (d) responsible person quickly decided to evacuate, and (e) all of the personnel at least could walk by their own legs.

ERSS archive [3] contains the evacuation performance data of organizations as well as that of residents. In the case of Ishinomaki and Onagawa, the sample rate for organizations having over 10 personnel was 9.0% and that for less 10 personnel organizations was 1.1%. Data concerning organizations located in the inundation area of Ishinomaki plain part were extracted and the main items about their evacuation performances are listed in Table 1. Data about above mentioned 3.1 – 3.9 organizations were not included in the sample. Table 1 clearly shows that the larger the organization the better the performance of evacuation realized. The table also shows the residents data for a comparison. The residents' poor performance were especially evident on information collection and safety confirmation of their family.

Table 1 – Tsunami evacuation performances of organizations and resident (from ERSS archive data)

	Number of personnel			Resident *1
	≧30	29 – 10	9 – 1	
Fatality rate of personnel	1.8%	1.6%	4.2%	2.3%
Feeling the strong earthquake, thought a tsunami must or may come	60.0%	50.8%	46.0%	46.4%
Recognized the warning of a large tsunami issued by JMA	80.0%	85.7%	66.0%	55.0%
Did information search and collection about the ongoing tsunami	80.0%	79.4%	76.0%	9.6%
Checked the hazard map distributed by Ishinomaki city office	24.0%	7.9%	8.0%	14.8%
Had a disaster management plan	64.0%	49.2%	26.0%	23.6%
Did safety confirmation on personnel	92.0%	81.0%	82.0%	26.1%
Had a disaster management staff	40.0%	15.9%	14.0%	
Total number of sample	*25*	*63*	*50*	*1,266*

*1 The residents in the inundated area of Ishinomaki plain part were concerned, the sample rate was about 2%

4. Evacuation of Individual Residents

4.1 Location of victims

Fig.7 is a plot of the location of residences of victims who died due to the tsunami in and around the study area. It should be noted that the residence locations were not always the same as the place of death. But, as mentioned in the below section 4.2, about 80% of residents were at home or returned home in the period between the earthquake occurrence and the tsunami's arrival. It is clear that the plots in the study area are denser than that in other areas of Ishinomaki and seem to be uniformly distributed.

Miyagi Prefectural Police confirmed the number of bodies in the study area as 294 (including non-residents in the study area), of which 7 were in Hibarino, 74 were in Minamihama, and 213 were in Kadowaki. The total number of the deceased who were living in the area was 493 (including missing people), including 6 in Hibarino, 275 in Minamihama, and 215 in Kadowaki. The small number of bodies found in Minamihama seems to be because a large number of people were washed away to other areas or carried to Kadonowaki in their floating houses or on the way to their evacuation destination on a hill.

4.2 Investigation of victims' behaviors based on information from survivors

When conducting the posting survey of residents of temporary housing in Ishinomaki, if the respondents had some information about close relatives, acquaintances, and neighbors who had lost their lives, they were asked to describe the situation on a voluntarily basis. Respondents were requested to select one of the situations of death listed in Table 2. Since the respondents who actually saw the situation at the time of the death were limited, information based on guesses or word of mouth inevitably increased. Therefore, respondents were asked to respond based on three choices regarding the certainty of their information (1. Almost no doubt, 2. Possible, 3. Unclear). In addition, as supplementary information, the names of victims, approximate age, gender, number of families who died together, and place of death were requested.

There were 797 respondents to the posting survey, and the response rate to this item was around 50%,

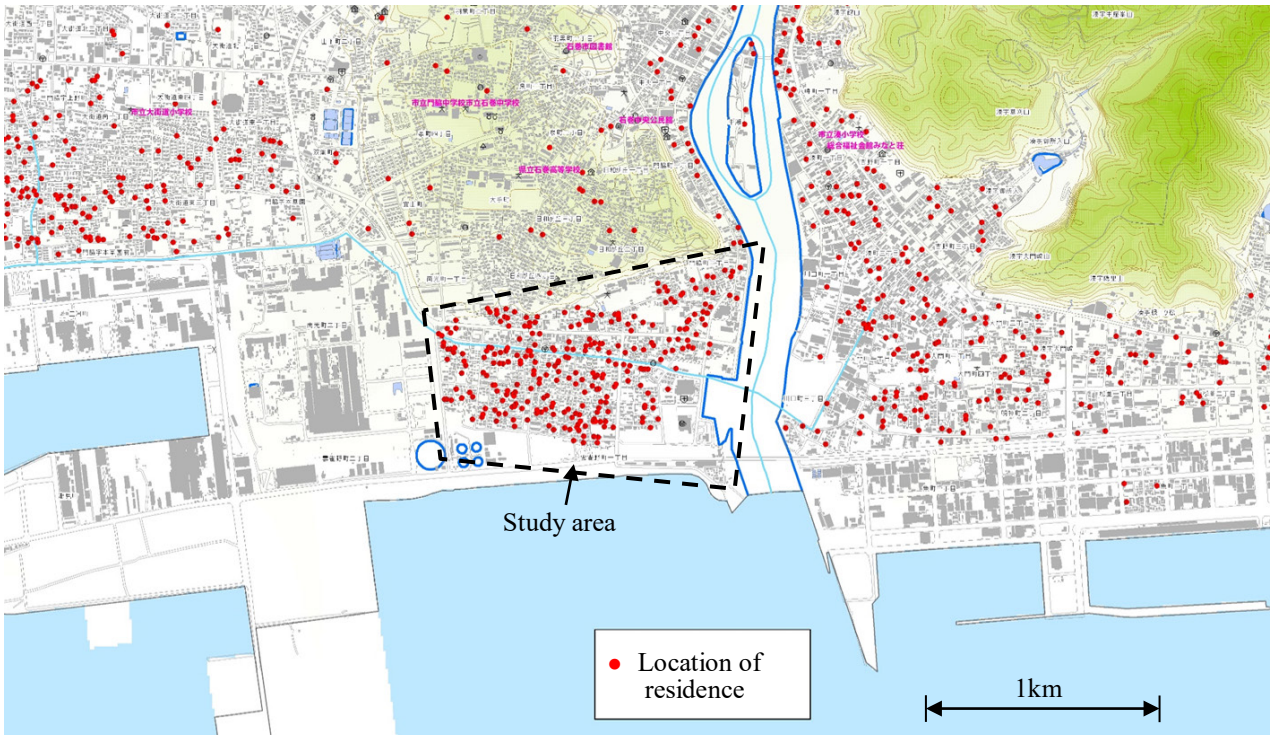
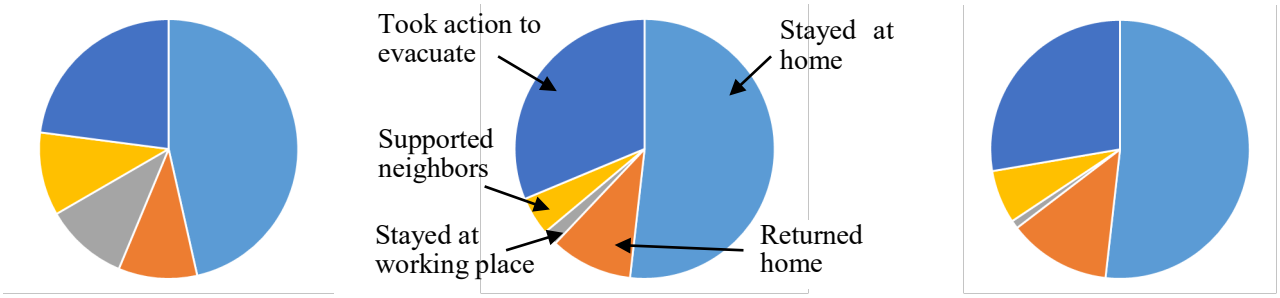


Fig.7 – Location of residences of the victims who lost lives due to the tsunami

but in many cases one respondent answered several victims, and the number of answers of accuracy 1 and 2 was reached 1,441 victims. However, when conducting this kind of survey, respondents tend to select tragic cases, such as evacuating by car and losing the whole family or dying together with a family on a sickbed, so overlap may have occurred. Therefore, supplementary information of the answers were compared, and if they were duplicated, one was deleted. The apparent overlap rate was 4.7%. Furthermore, only the data of certainty 1 were aggregated.

The responses were divided into the rias part (including Onagawa, see Fig.1), the plain part (see Fig.1) of Ishinomaki (including the study area), and the study area, which was included in the plain area. Victims' actions were divided into five patterns, namely, stayed at home, returned home, stayed at working place, supported neighbors and took action to evacuate from home. Fig.8 shows the results. It is clear that two thirds of victims those who stayed at home or returned home and died without clear action to evacuate. The more detailed results are shown in Table 2.

Kanai et al [6] reported from their survey in Kamaishi, Iwate Prefecture that 58% of the tsunami casualties died at home. This is almost consistent with the above results because "retuned home" included some persons who reached home before the tsunami.



Ishinomaki rias part and Onagawa Ishinomaki plain part (study area included) Study area

Fig.8 – Location of victims

Table 2 – Situation at death (Data classified certainty "almost no doubt" were used)

Situation at death	Ishinomaki rias part and Onagawa	Ishinomaki plain part	Study area
Could not walk because of weak leg and died in home	9.29%	10.36%	13.33%
Chose not to evacuate and died in home	27.87%	27.59%	22.56%
Waiting for returning family and died in home	4.37%	7.42%	7.18%
Died in home accompanying a bedridden family member	4.92%	6.43%	8.72%
Sub total	*46.45%*	*51.80%*	*51.79%*
Returned home from evacuation shelter or on the go and died.	9.84%	10.25%	12.82%
Did not leave working place and died there	7.10%	1.64%	0.51%
Went to beach side to observe sea and died	2.19%	0.11%	0.51%
Went to beach to save a fishing boat and died	1.09%	0.11%	0.00%
Caught by tsunami while picking up child or elder	2.19%	2.94%	5.13%
Caught by tsunami while helping families and neighbors	4.92%	1.64%	1.54%
Fail to escape for voluntary fire brigade activity	3.28%	0.22%	0.00%
Caught by tsunami while evacuating on foot	8.74%	9.38%	11.79%
Caught by tsunami while evacuating by car	10.38%	20.28%	13.85%
The first evacuation site hit by a tsunami and died there.	3.83%	1.64%	2.05%
Total number of data	*183*	*917*	*195*

In the Ishinomaki rias part and Onagawa, comparatively less residents died in their homes but many people died in their working places. The rias area is a tsunami-prone area, and the residents of that area had been quite conscious of the tsunami, but the tsunami height of the Great East Japan Earthquake exceeded 10m in this area. Several reinforce concrete buildings having two or more stories were located near shore for hospital or business use. Many victims seemed to have thought that their buildings were high enough, but the height of the tsunami far exceeded than their expectation. However, the percentage of those who died because of their inability to walk or were care recipients was low. One of the characteristics of this area is that the community is strong, and it is probable that weak evacuees were helped by people around them. On the other hand, it is also characteristic that 10.4% of victims died trying to help neighbors and participating voluntary fire brigade activities. The ratio of deaths among those who fled by car was relatively small. This was probably due to low traffic congestion.

In the study area, many people died trying to return to their homes from evacuation shelters. In fact, at Kadowaki Elementary School, many evacuees were seen returning home. There seemed to be various reasons for this, such as judging that the tsunami would not come, returning for medicine, getting winter clothes or saving a pet, but the actual situation could not be revealed by this kind of investigation. It is true, however, that there was no strong leader to hinder those who were going to return home. This becomes clear when comparing the situations based on the survivor witnesses. Table 3 shows that evacuation guidance by the voluntary fire brigade or other public organizations in the study area was less than that of the Ishinomaki rias part and Onagawa.

Another characteristic of the study area was that the proportion of fatalities from car evacuation was somewhat lower than that of the entire plain of Ishinomaki. Residents in this area were familiar with the local road conditions, and if they could not move due to traffic congestion, it was likely that they gave up early and climbed to a nearby hill on foot.

It should be noted that, those who could not escape due to poor foot conditions and died at home had an average age of 74 and as described in section 4.3 below, the average age of those who stayed at home but survived was 64. There is no doubt that movability was one of the factors that led to the difference between life and death.

4.3 Investigation of victim behavior based on information from survivors

There were 107 respondents to the posting survey in the target area. 57 were at home at the time of the earthquake, and 23 had returned home after the earthquake and before the tsunami hit. Of those 80, 62 evacuated and 17 did not evacuate. Since the number of survivors obtained by subtracting the number of victims from the population is 3,936, the number of survivors who had been at home was estimated to be 2,943 (80/107 of 3,936), and those who did not evacuate was estimated to be 625 (17/80 of 2,943). However, the estimated number of victims in the study area was 487, and 252(51.8%) were at home, as shown in Table 2. Therefore, 871 (625+252), around 30% were at home when the tsunami hit. Of course, some of those who stayed at home, went out to pick up their families or were looking around the neighborhood until the tsunami

Table 3 – Evacuation guidance on street

	Ishinomaki rias part and Onagawa	Study area
Nothing	33.8%	57.7%
Called by neighbors or people passing by	41.9%	23.1%
Calls and guidance from local government officials	5.4%	6.4%
Guidance from the company or organization at work	0.0%	2.6%
Calls from schools or public facilities to people in vicinity	5.4%	6.4%
Evacuation guidance on street by police or voluntary fire brigade	13.5%	3.8%
Total number of data	*74*	*78*

Table 4 – Reasons for not evacuating

I thought the tsunami wouldn't reach where I was	30.6%
When the tsunami came, I thought I should escape to the top of my house or a nearby building	4.5%
I didn't know what to do	7.0%
I tried to escape, but the tsunami came while I was checking surroundings.	19.1%
Subtotal	*61.2%*
I was looking for my family and relatives, or waiting for my family to return.	5.1%
I thought my feet were too weak to evacuate to the evacuation site.	3.2%
It was difficult to evacuate with a family who needed care.	7.6%
I stayed at work because I needed to play a role at work.	3.8%
There was an atmosphere where I could not leave my post at work.	1.9%
Other	14.0%
Total number of data	*157*

hit. And when they saw the tsunami actually coming, some of them might have popped out from their houses. But, the important point is that nearly one-third did not escape for some reason or did not take active evacuation action.

The number of persons who did not evacuate (survived without evacuating) was 157 in the plain part of Ishinomaki and 17 in the study area. Since there was too little data of the study area, the data from the plain part of Ishinomaki were analyzed and are shown in Table 4. 61.2% of the reasons were categorized as "they did not evacuate due to lack of awareness of the danger of tsunami". It is also noteworthy that 5.1% of respondents were "looking for their family or waiting for their return" and 10.8% of respondents were "disabled or stayed with a care recipient."

5. Note on the Hazard Map of Ishinomaki

25% among 109 respondents said that they "participated almost every year" or "participated occasionally" in local disaster prevention drills. However, many respondents in the Ishinomaki plain part said that the evacuation drills for tsunami were not conducted and the drills were no use for tsunami evacuation.

It has already been mentioned that the hazard map created by Ishinomaki City Office underestimated the flooded area. Even if a majority of people would not look at the hazard map, if the inundation area is upgraded, the disaster prevention information that the Ishinomaki City Office sends to residents and the content of disaster prevention drills in inundation-prone areas would need to be changed, and local mutual assistance systems to support for vulnerable evacuees, would need to be developed.

Ishinomaki City Office created a hazard map based on the tsunami inundation area prediction map prepared by Miyagi Prefecture in March 2004. According to the report on the Miyagi Prefecture Earthquake Damage Estimation Survey (March 2004 Miyagi Prefecture Disaster Prevention Council Special Committee on Earthquake Countermeasures, [7]), a tsunami propagation simulation assuming a linked (M8) hypocenter model off the coast of Miyagi prefecture was performed and the estimated inundation area were plotted. Fig.9 shows the linked hypocenter model. However, in the first chapter of the

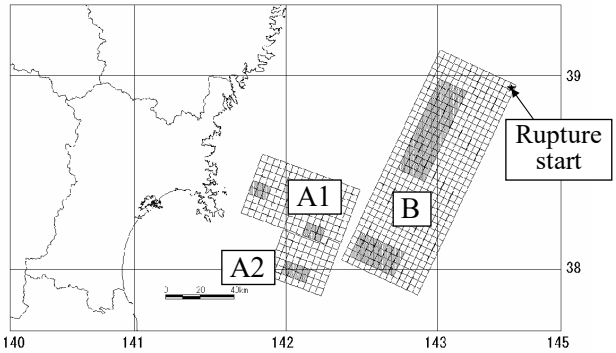


Fig.9 – Interlocked type fault model used by Miyagi prefecture, 2004

report, the following was stated: "The actual earthquake and the actual amount of damage may be different from the estimated result. When it is applied, it is necessary to understand the nature of the survey. And when creating a hazard map using these results, a workshop with the participation of the residents should be conducted".

It should be noted here that the tsunami deposits in the Sendai plain and the Ishinomaki plain have been surveyed since about 2001, and that in 2007, Shishikura and seven others [8] were estimated to be due to the Jogan Tsunami (AD869). They reported that the Jogan tsunami might have reached the vicinity of the Sanriku Expressway in the Ishinomaki plain and the innermost part of the Watanoha lowland, that is, it reached area equivalent to the tsunami hit area of the 2011 Great East Japan Earthquake. In addition, Satake and two others [9], in 2008, analyzed the tsunami deposits area of the Jogan Tsunami in the Ishinomaki and Sendai plains using a tsunami simulation with many hypocenter models, and reported that the distribution of tsunami sediment could be well explained if the dislocation was more than 7m and Mw was 8.4. The location of the presented source fault extended the hypocenter model assumed by Miyagi Prefecture about 100km further south-southwest.

The government's Headquarters for Earthquake Research Promotion prepared a draft on long-term evaluation of seismic activity in January 2011. According to this draft, the time interval of the sediment due to a huge tsunami on the coast from central southern Miyagi to central Fukushima was about 450 to 800 years and noted that an earthquake with a huge tsunami could occur at any time to these regions. Kunihiko Shimazaki (Professor Emeritus, The University of Tokyo), who served as a chairman of the long-term evaluation committee at the time, who was interviewed by a newspaper, said that it took time to correct the expression in the draft and to explain it to related organizations. Hence, its disclosure was postponed until April and, he said, it had not been in time for the Great East Japan Earthquake [10].

What would have happen if this draft had been released before the Great East Japan Earthquake? Following the announcement of the long-term assessment, could Ishinomaki change its hazard map and shift its policy to quickly strengthen tsunami countermeasures? Could residents increase their awareness and preparedness for tsunami risks? A large municipal hospital, a cultural center building, and many municipal homes and factories are already in the study area. This is only inference, but maintaining these land use conditions requires construction of a large seawall. It is costly, time consuming and ruining land utility. A tough and long term discussion would have been necessary.

6. Conclusions

(1) Considerable number of organizations in Ishinomaki were success in evacuation. Their common features are: (a) the organizations were aware tsunami risk, (b) their evacuation destinations were hill, (c) frequent drills had been done, (d) information were collected systematically, (e) responsible person quickly decided to evacuate, and (f) most of the personnel could walk by their own legs.

(2) In contrast, the evacuation of individual residents in the study area was disorderly. In the hazard map distributed by Ishinomaki City Office, Kadowaki Elementary School was assigned as an evacuation site in the event of a tsunami, and no tsunami inundation was expected in the Kadowaki and Minamihama areas. Residents' awareness of tsunami risk was generally low and no tsunami evacuation drills were carried out as part of the area's disaster prevention activities. Effective action of community leaders and onsite staff of public sectors to guide residents' evacuation from the tsunami were not reported in the study area.

(3) Car evacuation seemed not to be the biggest reason for the high human damage in the study area. There assumed to be not many local residents among those who were in lines on the arterial road. There were many cases where residents in the area managed to avoid traffic congestion even when they evacuated by car because they knew local detours. Some of them left their cars on the way and climbed up hill on foot.

(4) The biggest reason for the tragedy was that many residents stayed at home and did not attempt to evacuate. Reasons for this included a lack of vigilance against the tsunami, and many were hesitant to evacuate because of their weak feet or intentionally stayed in order to care for bedridden family members.

(5) It is assumed that a considerable number of people returned home after evacuating and many of them died. According to the testimony of a person who once returned home and evacuated again, she returned to get familiar household items such as winter clothes and canes. Along with improving the awareness against the tsunami, the review of facilities at evacuation shelters should be considered.

(6) There were many testimonies that about 20 minutes before the tsunami reached the study area, they heard on the radio that a large tsunami was hitting Onagawa. If there was a mechanism to more quickly and reliably transmit the actual tsunami risk to residents, their evacuation behaviors would have been different.

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