

FACT-FINDING ABOUT EVACUATION FROM THE UNEXPECTEDLY LARGE TSUNAMI

Task team on Yamada-machi and Ishinomaki-shi, Tsunami Evacuation Survey Group of the
Great East Japan Earthquake Disaster

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ABSTRACT: Almost twenty thousand people died in a region where the disaster preparedness level was thought to be relatively high. The truth about why so many people had to die was surveyed by a group of researchers and engineers to extract lessons for the community, municipalities and the next generation. About 1,300 evacuees in two typical areas were interviewed or subjected to a questionnaire. One of the areas was Yamada-machi, Iwate prefecture, which had a sawtooth coastline. The other was the coastal area of west of Ishinomaki-shi, Miyagi prefecture, which comprised flat land along Sendai bay.

Key Words: Great East Japan Earthquake, tsunami, evacuation, interview, questionnaire

INTRODUCTION

Almost twenty thousand people died due to the giant tsunami caused by the Great East Japan Earthquake, even though the earthquake occurred in daytime, the tsunami took at least half an hour to arrive at coast line and people in the region should have been at a relatively high disaster preparedness level. The purposes of this survey were to find the truth about why so many people had to die and to extract lessons for the community, municipalities and the next generation.

At the beginning of the survey, a group was established consisting of researchers and engineers who were interested in determining the facts about the people's evacuation from the giant tsunami. The group was chaired by Professor Imamura of Tohoku University. It was separated into several task teams, which were assigned to different areas to avoid further traumatizing evacuees by overlap of the survey. Our task team was assigned to the following two areas:

Yamada-machi of Iwate prefecture (hereafter Yamada)

Yamada has a sawtooth coastline, and had a population of 19,270 and 7,182 households as of March, 2011 (statistic data of Yamada town office). The main business was culture fishery. Yamada had suffered destructive tsunami three times in the past 115 years. They were the Meiji Sanriku Tsunami (1896), the Showa Sanriku Tsunami (1933) and the Chile Earthquake Tsunami (1960). The main area

of the town was protected by sea walls 5-8 meters high.

The JMA Intensity of the shaking of the Great East Japan Earthquake was 5-lower (MMI 7-8). The maximum tsunami height was estimated to be 11-12 meters and it arrived about 35 minutes after the earthquake. The dead and the missing due to the giant tsunami numbered 743 (web page of Yamada of January 26, 2012), which was 3.9% of the population, and 10.5% of the people where the land was inundated (Miyazawa 2011). 2,762 houses collapsed or were washed away (web page of Yamada), which was about 38% of the houses in Yamada.

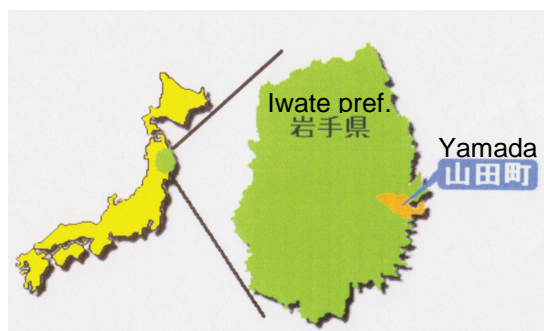


Fig. 1 Location of Yamada



Photo 1 Air photo of main part of Yamada

Ishinomaki-shi of Miyagi prefecture (hereafter Ishinomaki)

Ishinomaki has flat land in its southeast part along Sendai Bay. The population was 160,826 and there were 57,871 households as of 2010, October (census data). The main industries were fishery, fish processing, commerce, and paper manufacture.

The JMA Intensity of the shaking was 6-lower (MMI 9-10). The giant tsunami arrived about 40 minutes after the earthquake, and its maximum height was 4-5 meters along the coast of Sendai Bay. The tsunami inundated the flat and low area of the city, where the major population and industries had been concentrated. The dead and the missing due to the giant tsunami numbered 3,859 (Web page of Ishinomaki, January 30, 2012), which was 2.6% of the population, and 4.2% of the people where the land was inundated (Miyazawa 2011). 22,419 houses collapsed or were washed away (web page of Ishinomaki), which was 38.6% of the houses in Ishinomaki.

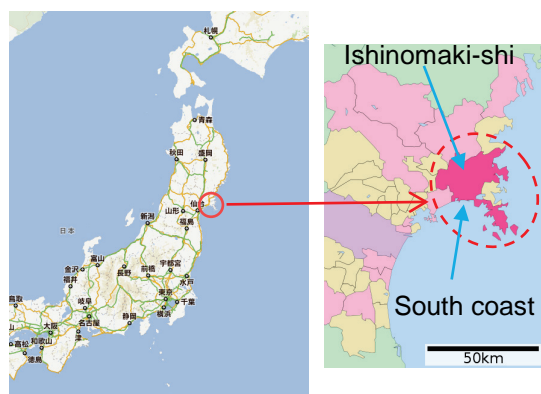


Fig. 2 Location of Ishinomaki



Photo 2 Air photo of south coast of Ishinomaki

Methods of survey

- 1) We visited evacuees in evacuee camps and temporary houses which were selected with consideration of the locations of the disaster areas, and interviewed them concerning how they survived and why their deceased neighbors could not escape from the giant tsunami. We also distributed questionnaires to the evacuees in temporary houses of Ishinomaki. The period of survey for Yamada was May to September, and that for Ishinomaki was October to December, 2011.
- 2) At the beginning of each interview, the interviewer handed a “sheet for trust” to the interviewee. The sheet described the purpose of the survey and how the results would be utilized, named the members of the task team, informed the interviewee of his free refusal right, and gave the interviewee the phone number of the interviewer. After obtaining the interviewee’s consent, the interviewer started conversation with the interviewee carefully and tried to elicit his or her answers to the questions during natural flow of communication.
- 3) During the interview, the interviewer was required to be a listener, to keep his eye-line lower than that of interviewee and to not interrupt the interviewee when he or she wanted to talk about something not directly concerned with the questions. As a result, the interview sometimes exceeded one hour.
- 4) On the “sheet for trust”, a contact phone number was written. Although about five hundred evacuees were interviewed, there were no complaint calls.
- 5) For the questionnaire, almost the same “sheet for trust” was attached as well as a return-mail envelope. Questionnaires were posted to 3,400 temporary houses and 797 were returned (collection rate 23%), and there were two phone calls: one was to confirm the nature of the task team and the other was to complain that his case did not match with the question items.
- 6) We also interviewed Yamada town office and Ishinomaki city office staff, fire brigade fire fighters, community fire fighters and police. We obtained many statistical data from these people.

RESULT OF SURVEY

Evacuation circumstances

The following Fig. 3 and Fig. 4 denote the sequence of the main shock and aftershocks and the alerts issued by JMA up to the arrival of the giant tsunami. Before the arrival of the giant tsunami, there were several aftershocks, which might have interfered with evacuation. JMA corrected the first alert and raised the expected tsunami height to double height by its second alert, but this was only 7-12 minutes before the arrival of the giant tsunami.

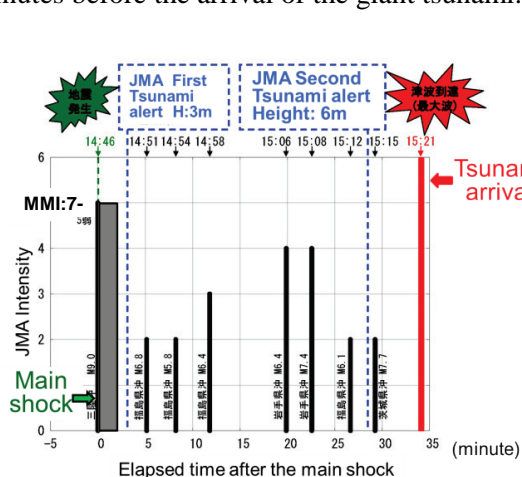


Fig. 3 Sequence of main shock, after shock, tsunami and alert in **Yamada**

Courtesy of Eight-Japan Engineering Consultants Inc.

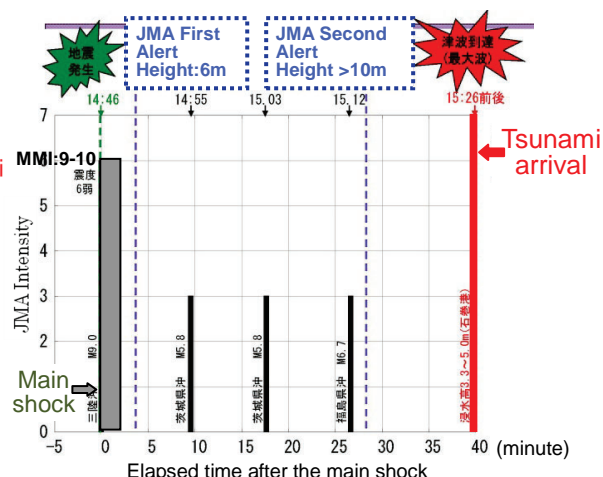


Fig. 4 Sequence of main shock, after shock, tsunami and alert in **Ishinomaki**

Courtesy of Eight-Japan Engineering Consultants Inc.

Table 1 and Table 2 list the alerts broadcast by outdoor loudspeakers of the emergency municipal radio communication systems of Yamada and Ishinomaki. Tsunami alerts were announced several times. It is supposed that most of the loudspeakers were undamaged by the shaking of the earthquake and functioned until their supporting posts were washed down by the giant tsunami. However, many of the evacuees complained that they could not hear the sound or could not distinguish the meaning.

Fig. 5 and Fig. 6 compare the age distribution of the dead with the age distribution of the whole population. The effect of age is clear. The age distribution of the dead was high, in the 60's-80's, and was more pronounced in Yamada. Originally, Yamada was a more aged society than Ishinomaki, which shows that an aging society is at more risk than a younger society. One of the tragedies in Yamada was that a large-scale care house was washed away by the giant tsunami, and 74 old people (10% of the dead in Yamada) and 14 staff lost their lives (Iwate Nippou, 2011).

Table 1 Contents of Yamada broadcast

Time	Contents
14:47	A large earthquake has occurred. Close sea wall gates and leave the coast
14:54	Large tsunami alert was issued. Expecting height is more than 3 meter. Evacuate. Close sea wall gates
15:13	As above
15:25	Evacuation order issued

Table 2 Contents of Ishinomaki broadcast

Time	Contents
14:48	A large earthquake has occurred. Large tsunami alert was issued. Leave the coast and river mouse. Avoid using cars
14:52	Repeated with some additional information
14:56	ditto
14:58	ditto
15:02	ditto
15:04	ditto
15:20	ditto
15:25	ditto
15:20	ditto
15:25	ditto

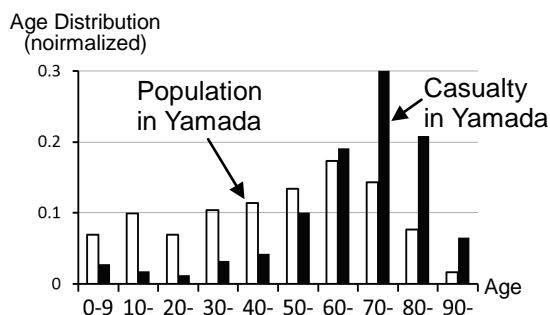


Fig.5 Age distribution of Population and Casualties of **Yamada**

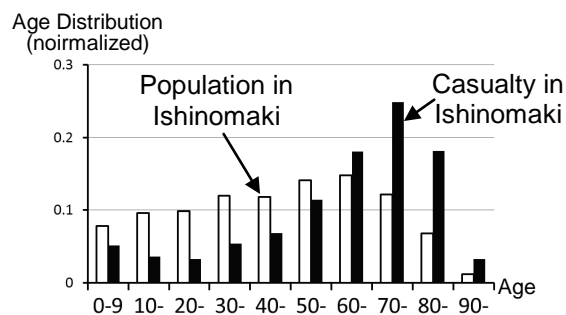


Fig.6 Age distribution of Population and Casualties of **Ishinomaki**

Disaster awareness

Disaster awarenesses in the two areas were different. Table 3 and Fig. 7 show the perception of risk that the evacuees in Yamada and Ishinomaki had during the strong and long-duration earthquake. The seismic intensity meter of Yamada was located on rather solid ground and the recorded intensity was assumed to be smaller than that of low ground near the sea. But still the average intensity in Yamada must have been lower than that in Ishinomaki. The strong earthquake did not raise the threat of a tsunami in the minds of many people in Ishinomaki.

Table 3 Tsunami risk awareness associated with feeling of strong earthquake

Did you think that a tsunami would come just after the earthquake?	Yamada	Ishinomaki
Large tsunami must come	44%	15%
Tsunami will come but not so large	36%	31%
Tsunami will not come	7%	22%
Not think about tsunami	12%	32%
Number of sample	200	289

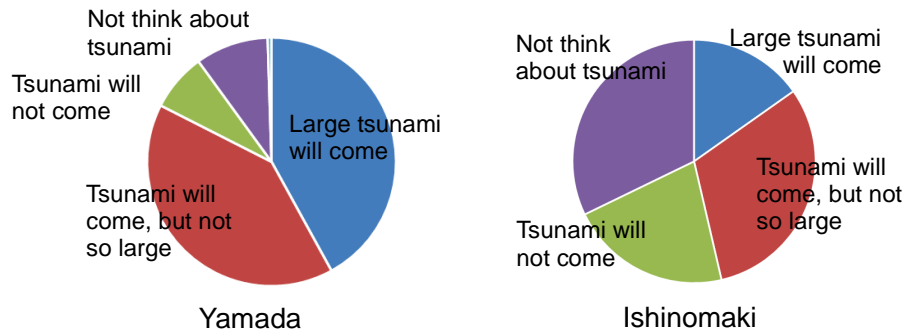


Fig. 7 Did you think that a tsunami would come just after the earthquake?

Table 4 shows actual actions of evacuees in Yamada and in Ishinomaki. In both areas, about two thirds of the people started to evacuate soon after the shaking went down. However, about one fourth of the people in Ishinomaki did not evacuate before the tsunami arrived. Table 4 also shows that 14% of evacuees in Yamada started evacuation during the shaking. This may also show high awareness of the people in Yamada. But, we should take the aftershocks' sequence into consideration when analyzing this data. People in Yamada might have been feeling continuous shaking for some period after the end of the main shock, as shown in Fig. 3.

Table 4 Timing of beginning evacuation

When did you begin evacuation?	Yamada	Ishinomaki
During shaking	14%	1%
Soon after earthquake stopped	53%	63%
Just before tsunami arrived	17%	9%
After tsunami arrived	9%	22%
Due to fire or others	7%	5%
Number of sample	200	290

Fig. 8 shows other differences of tsunami awareness. About three fourths of the evacuees in Ishinomaki had not thought specifically about tsunami risk and evacuation before the giant tsunami of March 11, 2011. This low awareness of tsunami risk might have been because of the low estimation of tsunami run-up height denoted by the official hazard map.

Fig. 9 shows the tsunami hazard map in the south west area of Ishinomaki, and Fig. 10 shows the actually observed area inundated by the giant tsunami of March 11, 2011. Many of the evacuees in Ishinomaki had not seen this hazard map, but the low estimation of tsunami risk might have been passed on to them by word of mouth.

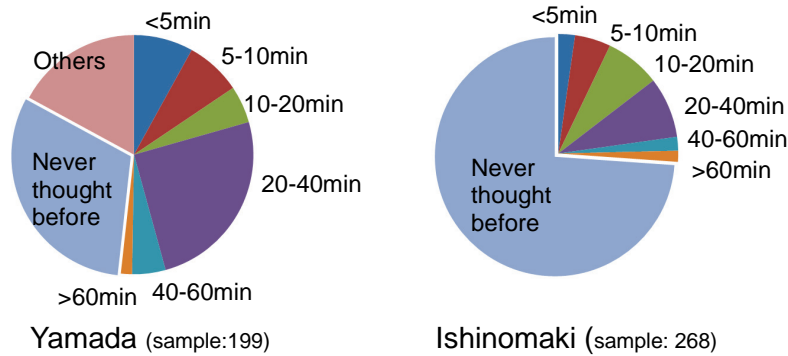
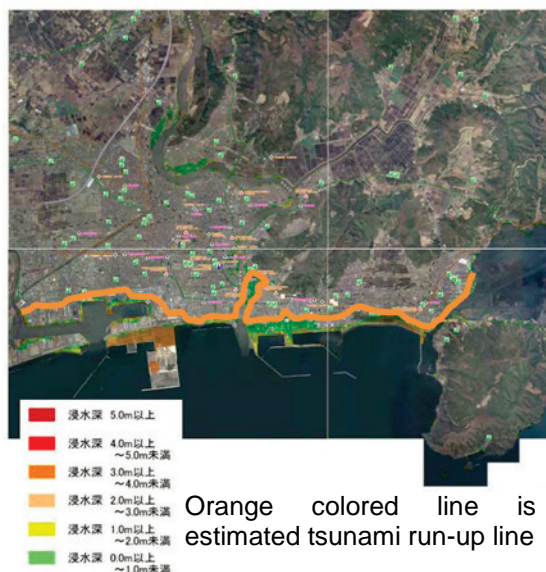
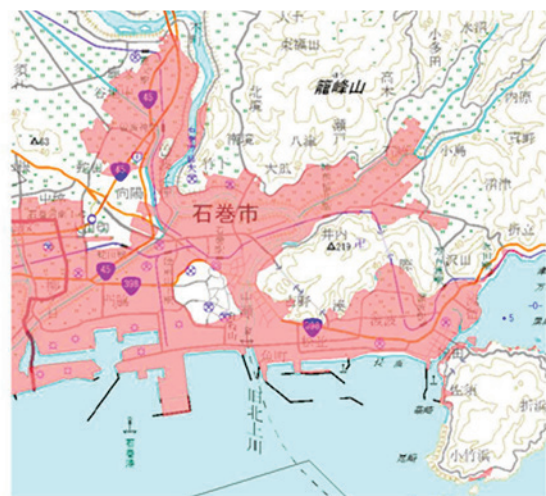


Fig. 8 Before you experienced March 11, what had you thought the time interval would be between earthquake and tsunami arrival?



Attached to "Hazard Map of Ishinomaki"
http://www.city.ishinomaki.lg.jp/static/guide_ishinomaki/tsunami/

Fig 9 Hazard Map for south west area of Ishinomaki



Orange colored area was actually inundated

Geospatial Information Authority of Japan
<http://www.gsi.go.jp/kikaku/kikaku60003.html>

Fig 10 Tsunami inundated area by March 11, 2011 great tsunami

The difference of disaster awareness also appeared in the rate of participation in disaster drills (Fig. 11). The ratio of people who had not participated in a disaster drill was one third in Yamada, but two thirds in Ishinomaki. In Ishinomaki, disaster drills were conducted by communities supported by the city office, but participation of people had been generally low. Moreover, almost all the drills had focused to earthquake and fire. This low tsunami-awareness level in the south-west area of Ishinomaki might have come from the disaster prevention plan of Ishinomaki, which had shown the expected tsunami height to be of small damage level, as the result that the tsunami expected through authorized procedures was not large along Sendai bay.

Fig. 12 shows the relation between quick evacuation and ratio of participation in annual disaster drills in Yamada. People who had participated in disaster drills every year evacuated quickly. In Yamada, evacuation drills had been conducted every year by the town office, and were participated in by 10-15% of its population.

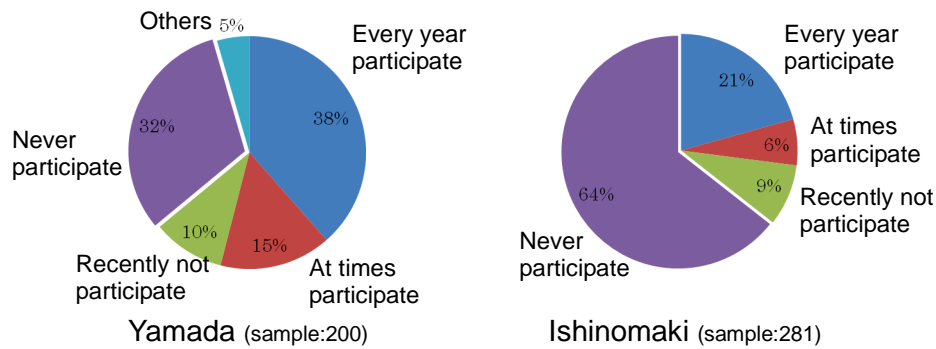


Fig. 11 Did you participate in disaster drill?

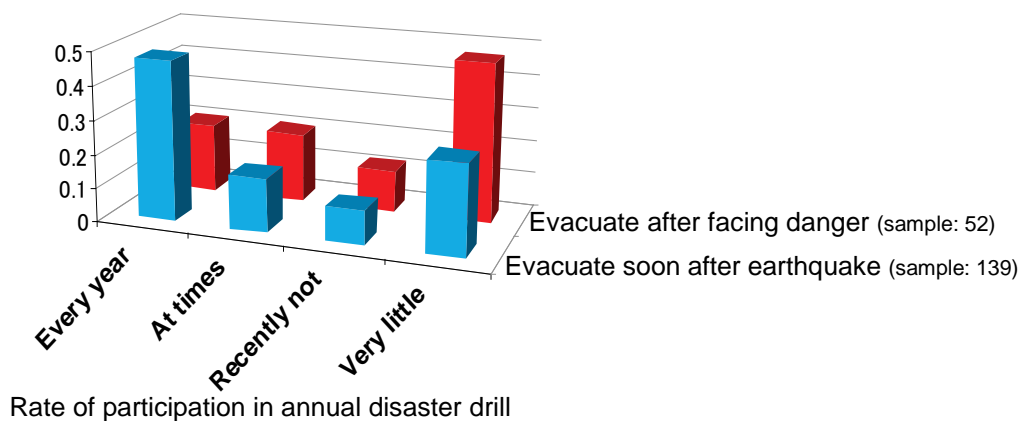


Fig. 12 Quick evacuation vs. rate of participation in annual disaster drill

“Tsunami Tendenko” and mutual cooperation

Fig.13 shows the answers to the question about with whom the evacuee evacuated. In Yamada, evacuation alone was about twice that of Ishinomaki. That is, “Tsunami Tendenko”, which is a traditional tsunami disaster phrase meaning “evacuate by oneself and do not care about others”, was carried out more honestly. In Ishinomaki, however, it is also important to note that families, neighbors and community leaders helped people to begin to evacuate (Table 5). Many people alerted their neighbors who were lacking information. They also helped vulnerable neighbors to evacuate.

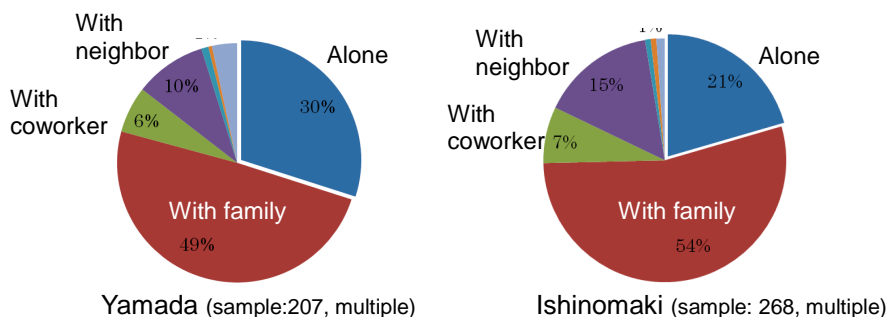


Fig. 13 With whom did you evacuate?

Table 5 Trigger to person evacuating

What was the trigger to you evacuating	Yamada	Ishinomaki
Feeling large and very long shaking	54%	27%
Hearing alert of large tsunami	10%	19%
Guide of head of family	6%	18%
Following neighbor's evacuation	3%	6%
Community leader's guide	6%	15%
Seeing receding tide	1%	0%
Seeing tsunami coming	11%	5%
Seeing tsunami crashing over seawall	1%	1%
Fire, others	8%	9%
Number of sample	179	215

Table 6 shows what the evacuees were doing until beginning evacuation or being caught in the tsunami. It should be mentioned that in Ishinomaki the ratio of evacuees who tried to pass alert of risk to neighbors and helped others to evacuate was considerably larger than that of Yamada. However, it might be oversimplifying to explain this discrepancy by the difference of humanity in these two areas. Only 7% of Yamada evacuees tried to gather up mess caused by the earthquake, while 20% of Ishinomaki evacuees did. People in Yamada might have had much more feeling of crisis and might not have been able to afford to think of helping others.

Table 6 Behavior just after earthquake, up to evacuation or tsunami arrival

What were you doing until starting evacuation or being caught by tsunami	Yamada	Ishinomaki
Going back to home	15%	12%
Going back to home to help family to evacuate	8%	7%
Going to collect family in school or somewhere	6%	6%
Going to sea side to look at sea	7%	1%
Collecting important goods	38%	28%
Locking my house	14%	8%
Picking up items scattered by the earthquake	7%	20%
Making phone calls or sending e-mail to relatives	3%	4%
Remember nothing	2%	3%
Doing nothing, evacuated immediately	20%	23%
Passing alert of risk to neighbors	2%	9%
Helping handicapped people to evacuate	3%	5%
Number of sample (multiple answer)	200	280

Information triggering evacuation

Fig. 14 shows the evacuees' information sources of tsunami alert. TV was generally no use because electric power went down during the earthquake in both Yamada and Ishinomaki. Therefore, outdoor loudspeaker of the emergency-municipal-radio-communication-system (hereafter EMRCS) was the most important tool for transmitting disaster alerts to people. The contents of announcements after the earthquake until the tsunami's arrival are shown in Table 1. The second most important information source in Yamada was portable radios or car radios, but in Ishinomaki it was word of mouth from neighbors.

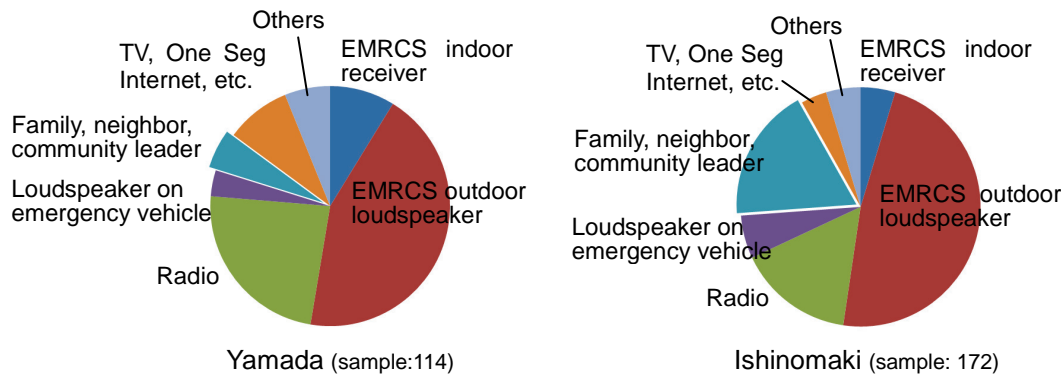


Fig. 14 Information source of large tsunami alert

Whether or not the announcements reached people is shown in Table 7. The alert did not reach 36% of people in Yamada and 49% in Ishinomaki, including those who “Do not remember”. Many evacuees, especially in Ishinomaki, complained that they could not hear the sound or could not understand announcements from outdoor loudspeakers. Although most of the speakers were functioning before the tsunami arrived, the volume might have been too low for people indoors or might have had too much echo for people outdoors. Many evacuees stated that the speech tone lacked a sense of crisis for a person who was in a hurry to evacuate.

Table 7 Informativity of loudspeaker for tsunami alert

Did you hear the tsunami alert by EMRCS	Yamada	Ishinomaki
Heard before or during evacuation	46%	43%
Heard after evacuation	10%	7%
Do not remember	36%	10%
Could not hear or could not understand	-	39%
Others	9%	-
Number of sample	200	281

Did the large tsunami alert enable people to evacuate or not?

We asked evacuees which was the key factor that decided them to begin evacuation. The result is shown in Table 5 above.

In Yamada, more than half the evacuees answered "very long strong earthquake", and a few of them answered "large-tsunami alert ". In Ishinomaki, these two factors came closer to the same level, but more evacuees answered that "information from people such as family, neighbor and community leader" was the key factor.

In conclusion, "large-tsunami alert" was not the key factor in both areas. JMA issues tsunami alerts as a task and there have been many discussions on ways of making announcements in the early stage after a M9.0 huge earthquake. But, the alert was not the key factor in people's decision to begin to evacuate. If the electric power had not been cut and most people could have obtained information from TV, some information from JMA, such as the expected time of the tsunami's arrival and the observed tsunami height in the early stage, might have confused people in the area.

Evacuation method

Fig. 15 and Table 8 denote evacuation methods and their efficiencies. One third of the evacuees in Yamada and 56% of those in Ishinomaki did use cars to evacuate. In Ishinomaki, many encountered

traffic jams. 11% of car evacuees were forced to leave their cars to escape, or stay in their cars and be caught by the tsunami. We must note that these data came from survivors. If data from the dead were included, the ratio of those caught in their cars would somewhat increase.

There have been many discussions about the demerits of evacuation by car. However, during our interview survey and questionnaire survey, we received many opinions which stressed the need for evacuation by car of old persons and/or disabled persons.

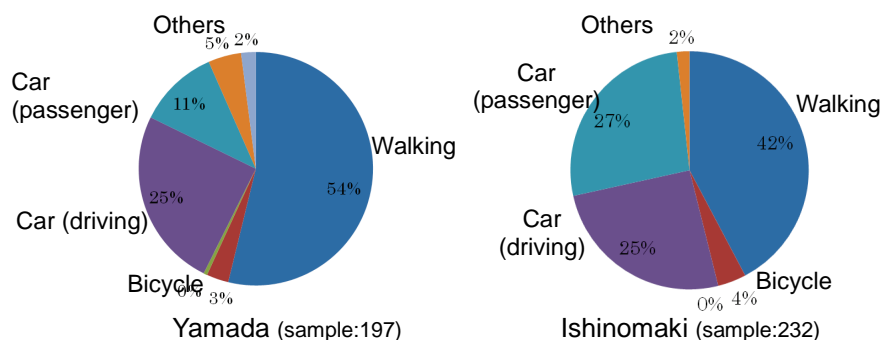


Fig. 15 Evacuation methods

Table 8 Traffic jam during evacuation

Was your car been trapped by traffic jam?	Yamada	Ishinomaki
Trapped in a traffic jam	10%	36%
Saw traffic jam but not trapped in it	13%	27%
Saw some rubbles tying up traffic	4%	3%
Did not see traffic jam	67%	23%
My car and I were caught in the tsunami	4%	5%
Trapped in traffic jam, escaped from car and ran	3%	6%
Number of sample	79	171

Effect of past tsunami experience

Some people did not evacuate but stayed on the second floor or roof of their house. They described why they did not evacuate. The results are shown in Table 9.

In both areas, about half the evacuees who did not evacuate thought the tsunami would not reach their houses. Many of the old people in these areas had suffered damage in the 1960 Chile Earthquake Tsunami and they thought that the tsunami height on that occasion was something like a standard. However, the height of the March 11, 2011 giant tsunami was three to five times larger than that standardized height. There had not been any destructive tsunami for 50 years, and, to make the situation worse, JMA had issued large tsunami alerts into this area several times in recent years, but people had not experienced a destructive tsunami.

Fig. 16 clearly shows the situation. The houses of persons who were washed out and died are shown by a blue dot on the figure. People living near the sea or river mouth did evacuate soon after the earthquake because they well knew the tsunami risk. As a result, there were few of casualties in these areas. However, along the foot of the hills, i.e. slightly higher land, there were many casualties. Apparently, people in these areas thought that as past tsunami run-ups did not reach the heights of their houses they did not need to evacuate. However, the run-up of the March 11 giant tsunami was much higher than previous ones.

Table 9 Reasons for not evacuating immediately

I did not evacuate because;	Yamada	Ishinomaki
I thought tsunami would not reach my home.	42%	42%
I thought sea wall would protect us.	3%	3%
I was waiting and seeing	10%	10%
I was taking much time to prepare evacuation	6%	6%
I was looking for or waiting for my family	7%	7%
I didn't know how to do	0%	4%
If tsunami came, I thought I could go up second floor	3%	1%
I would not have time to reach a safe place before tsunami arrived	3%	7%
I could not leave my work place	4%	4%
I evacuated due to fire, not by tsunami	11%	-
Others	16%	16%
Number of sample	28	73

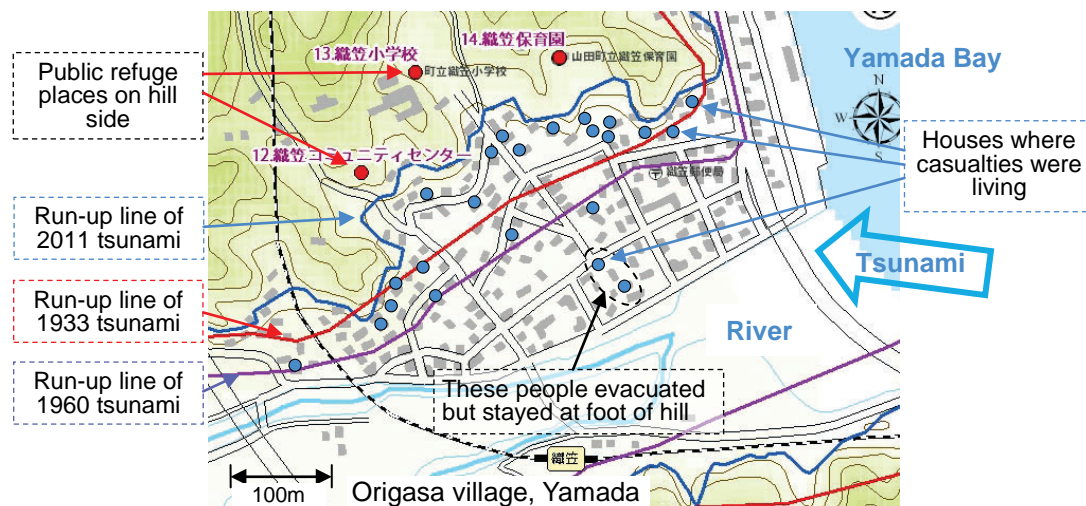


Fig. 16 People living at foot of hills believed their houses would be safe, but --.

CONCLUSIONS

- 1) The age distribution of the dead was concentrated in the 60's-80's. Many of these old persons could not move well. Even if they could walk, they tended to avoid it and preferred to go up to the second floors of their houses. However, the giant tsunami easily washed away their wooden houses.
- 2) Young families, sons and daughters or grandchildren of these old persons, went back home from downtown in order to rescue them. Some of them succeeded and some of them were washed away with their old relatives. We should discuss "Tsunami Tendenko" after learning this fact, and must deepen our thinking concerning reduction of car evacuation after learning that cars were indispensable to save these families.
- 3) Experience of past tsunami disaster was not always helpful. People living in high risk regions such as coastal areas and river mouths generally had enough awareness of tsunami risk from their experience or from the word of mouth of their parents. They quickly evacuated after the earthquake.

However, people living on slightly higher land where the tsunami run-up of the 1960 Chile Earthquake Tsunami did not reach over-estimated the safety of their houses.

4) The large-tsunami alert broadcast by the emergency-municipal-radio-communication-system was not effective. Many people decided to evacuate based on their feeling about the strong and abnormally long earthquake. Many people also could not understand the echoing voice from the loud speakers. Moreover, many evacuees said that they had thought the large tsunami alert issued by JMA might be "the boy who cried wolf" this time too.

5) There was a clear difference between the tsunami risk awarenesses of the people in the two regions, one of which has a sawtooth coastline facing the Pacific Ocean and another of which has a plain coastline facing Sendai bay. In the latter case, not only individual citizens but also local communities and sectors lacked tsunami risk awareness. Disaster drills were conducted every year but most of them focused on earthquake and fire. Some public refuge places were located in low land near the sea.

This low awareness might have resulted from the hazard map compiled by the local government. This map was of course based on advanced scientific knowledge and technology at that time and actually this area had not experienced a very large tsunami in recent years, but still the past inadequate contribution of science and engineering on raising disaster awareness is regretted.

6) In the high-risk area, people's tsunami awareness was high but their spirit of mutual aid was relatively low when compared to that of the people in what was thought to be the lower risk area. This discrepancy must be surveyed more deeply.

7) This paper is based on a part of the data surveyed by the task team on Yamada-machi and Ishinomaki-shi, Tsunami Evacuation Survey Group of the Great East Japan Earthquake Disaster. Analyses on the whole data are still on-going.

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