

HOW DO COASTAL RESIDENTS BEHAVE AFTER A BIG EARTHQUAKE? :

A QUESTIONNAIRE SURVEY AFTER THE GREAT EAST JAPAN EARTHQUAKE AT ONJUKU, CHIBA PREFECTURE

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Abstract: A massive tsunami generated by the Great East Japan Earthquake caused serious damage to the coast of the Tohoku and Kanto regions. Since evacuation delays caused many casualties, we must reconsider our approaches to disaster education and post-emergency announcements. To do so, it is important to understand how coastal residents made decisions and how they behaved after the earthquake. In this study, we conducted a questionnaire survey in Onjuku, Chiba prefecture. Questionnaires were distributed to all households in the coastal area of the town. Residents were asked about their behaviors using a flowchart and a map; these allowed us to identify respondents' locations at the time of the earthquake and trace their subsequent behaviors as well as the reasons for their choices. Based on 447 valid responses, we identified the factors influencing residents' decision-making and route choices. Behavior patterns differed based on residents' locations at the time of earthquake, and we identified several types of risky behavior.

1. INTRODUCTION

The Great East Japan Earthquake that occurred on March 11, 2011 generated a massive tsunami and caused serious damage along the coast of the Tohoku and Kanto regions. Most of the 23,000 persons who were killed or missing drowned as a result of the tsunami. Although many researchers have pointed out that the most effective way to reduce tsunami-related fatalities is early evacuation (e.g., Hirose, 2004, and Kuwasawa et al., 2006), delays or failures in evacuation in fact resulted in significant casualties. Therefore, it is important to investigate how coastal residents made their decisions and how they behaved during the emergency.

In 2008, Isagawa and Murao (2010) carried out a questionnaire survey investigating evacuation behavior and risk perception of tsunamis in Onjuku, in the Chiba prefecture. During the 2011 earthquake, no one was hurt in this town, although a large-scale tsunami warning and an evacuation counsel were issued to the coastal area.

In this study, we investigated the actual behavior of the residents of Onjuku after the March 11 earthquake. The results of this survey may suggest more effective ways of announcing emergencies and conducting disaster education.

2. METHODS

2.1 The research field

Onjuku is located on the eastern side of the Boso

Peninsula and borders the bay to the south (Figure 1). The central area of the town is located on lowlands. It is said that at the time of the Genroku Earthquake in 1703, an eight-meter-high tsunami hit the town and caused serious damage (Tsuji, 2003). Therefore, the local government prepared for subsequent earthquakes and tsunamis by creating a hazard map, providing evacuation shelters, and setting up an emergency broadcast system.

On March 11, 2011, at 2:46 p.m., an earthquake with magnitude of 9.0, centered on the Sanriku coast, resulted in tremors of an intensity of 4 on the Japanese seismic scale in Onjuku. Three minutes after the earthquake, the meteorological agency issued a tsunami warning for Pacific coastal areas, including Onjuku. At that time, the agency estimated the maximum tsunami runups in the area to be two meters high. Nearly half an hour later, the alert was upgraded to a large-scale tsunami warning with expectations of runups over 10 meters high.

Immediately after the first warning, the local government used an emergency broadcast system and cars with loudspeakers to begin announcing that a tsunami warning was in effect for the coast,

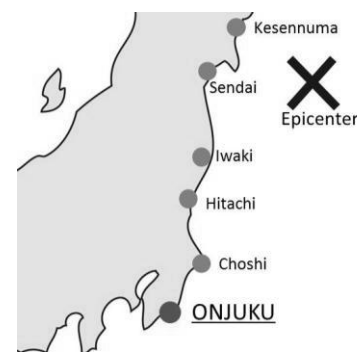


Figure 1 The location of Onjuku

and requested that people in coastal areas evacuate to higher ground. Furthermore, they issued an evacuation counsel to coastal residents at around 4:30 p.m. The first wave of the tsunami was observed at the coast of Onjuku at around 3:20 p.m. After that, tidal levels gradually moved up and down. Although the whole beach was flooded several times, no one was injured and buildings were not damaged. According to the Earthquake Research Institute at the University of Tokyo, the maximum tsunami height at Onjuku was 2.5 meters (Tsuji et al., 2011outline).

2.2 Outline of the questionnaire survey

We conducted a questionnaire survey in the coastal area of Onjuku at the end of July, distributing the questionnaires to all 2,272 households in this area. We asked that only those who were in the town at the time of the earthquake respond. The content of the questionnaire was divided into two parts. In the first part, we asked each respondent to describe the sequence of their behavior in the form of a flowchart, and to trace on a town map both their location at the time of the earthquake and their subsequent movements. In the second part, we asked the reasons for their behavior, for instance prior knowledge or information obtained since the earthquake took place. With these, we aimed to clarify the factors that influenced their decision-making and route choices.

By the end of October, we received 447 valid responses by mail, corresponding to a collection rate of 19.7%. Fifty-seven percent of respondents were female, and 71% were aged 60 or older. A total of 41% had no regular occupation, 22% were housewives, and 16% were salaried workers.

3. RESIDENTS' LOCATIONS AT THE TIME OF THE EARTHQUAKE AND ACQUISITION OF DISASTER INFORMATION

3.1 Location at the time of the earthquake

Figure 2 shows each resident's location at the time of the earthquake. A total of 74.5% of the respondents were in their homes, including 10% in multistory apartments located on the seaside. The rest were in offices or schools (8.3%), shops (2.5%), inside other types of buildings (5.3%), outdoors (4.8%), or in transit (3.7%).

Figure 3 shows how residents mentally associated the earthquake with the tsunami that hit the coast of Onjuku. Only eight percent of the respondents strongly connected the two, and 43.5% thought the tsunami would not affect the area or did not think of a tsunami at all.

3.2 Acquisition of disaster information

Thirteen percent of the respondents did not receive the tsunami warning on the day of the earthquake. Figure 4 shows the percentage of residents in each location who were aware of the tsunami warning. Compared with residents who were in their homes, offices, or schools, those who were in other types of buildings (including shops), outdoors, or in

transit were less informed about the tsunami warning. In particular, 8 of 12 residents who were outside the town and returned after the earthquake had not heard about the warning. These results underscore the difficulty in conveying disaster information to residents in all locations.

Figure 5 indicates the primary ways in which residents

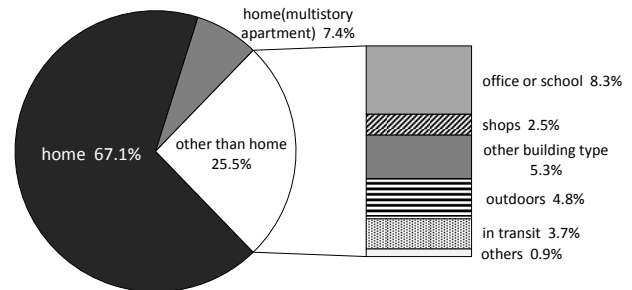


Figure 2 Residents' locations at the time of the earthquake (N=435)

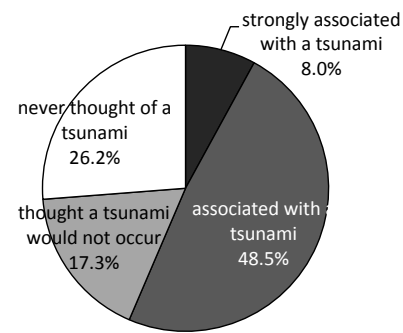


Figure 3 Residents' mental associations between earthquake and tsunami (N=427)

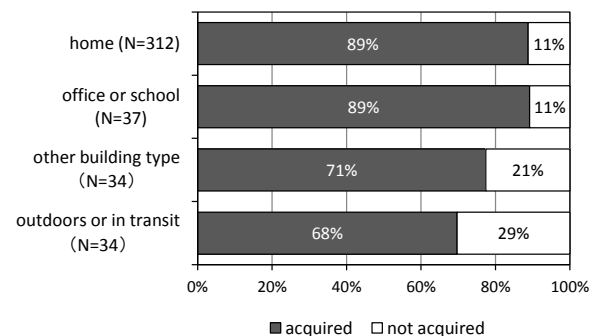


Figure 4 Awareness of tsunami warning on the day of the earthquake (by location)

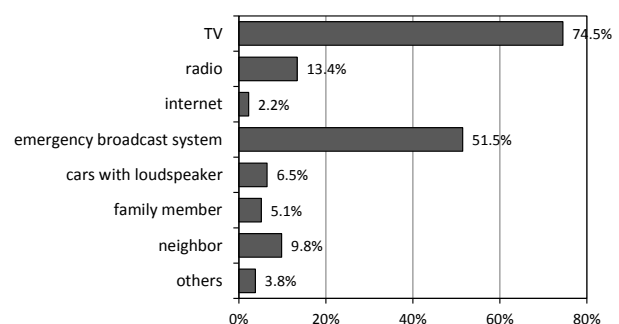


Figure 5 Acquisition of information about the tsunami on the day of the earthquake (multiple answer, N=447)

acquired information about the tsunami right after the earthquake. Information was obtained from television broadcasts by more than 74% of residents, and through the emergency broadcast system by approximately half.

4. COASTAL RESIDENTS' BEHAVIOR AFTER THE EARTHQUAKE

4.1 General tendencies

Figure 6 demonstrates residents' actions after the earthquake. Only 431 responses, excluding 16 responses with incomplete descriptions, were used for this analysis. About 40% of the respondents evacuated, 23% did not evacuate but moved elsewhere, and 35% did not move at all.

Figure 7 shows the means of transportation used for evacuation to shelters. Despite the government's encouragement to travel on foot during the emergency, over 75% used cars for evacuation. Some people evacuated on foot at first, but came back home in order to get their cars to travel farther away. This indicates that many residents strongly depended on cars.

Figure 8 shows who accompanied residents during their initial evacuation to shelters. Nearly 50% moved with some of their family members. Only 27% of residents evacuated alone.

4.2 Behavior patterns after the earthquake

Figure 9 illustrates residents' behavior patterns after the earthquake. Data obtained from those who moved immediately to attend to urgent tasks, for instance volunteer fire corps members are omitted here.

(1) Behavior patterns according to location

We found that behavior patterns differed greatly according to residents' locations at the time of the earthquake.

Residents who were in their homes

Behavior patterns were quite different depending on housing types, i.e., detached houses vs. multistory apartments. Nearly 40% of the residents in detached houses moved directly to shelters, while about 40% did not move anywhere. Twenty percent moved elsewhere then returned to their homes and did not go to a shelter. The left column of Table 1 shows where these residents stopped before going final destination (including those who were in the apartments). It should be noted that 24 people went to the coast to observe the sea, 15 people picked up their children or grandchildren from school, and nine went shopping.

Most residents of multistory apartments, made of reinforced concrete, did not evacuate. Only four of 32 residents evacuated to higher ground, and three of them reported that they did so because they were worried about their cars rather than themselves. Five residents did not evacuate because those houses were structurally strong enough to protect them and instead went shopping or observed the sea.

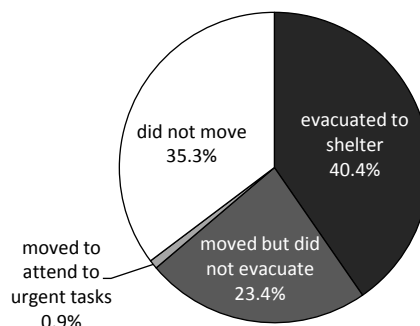


Figure 6 Residents' actions after the earthquake (N=431)

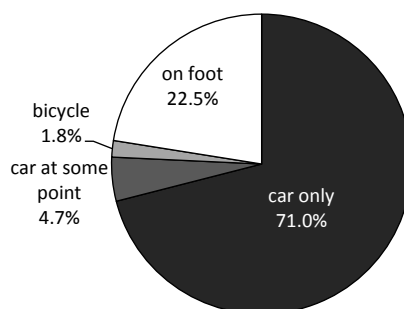


Figure 7 Means of transportation used for evacuation (N=169)

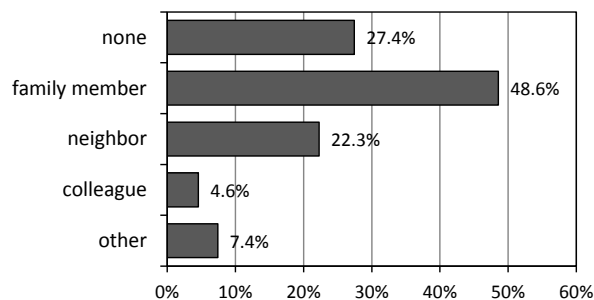


Figure 8 Resident's companions during initial evacuation (N=175)

Residents who were outside their homes

Compared with those who were in their homes, residents who were outside at the time of the earthquake rarely evacuated directly to shelters or stayed in place. The right column of Table 1 shows where these residents stopped before going final destination.

As for residents who were in offices or schools, their behaviors were divided almost evenly into four types: directly evacuated to shelters (nine people, including one person who evacuated to her home); evacuated to shelters after stopping somewhere else first (mainly their homes; six people); returned home and remained there (10 people); and remained in the building (eight people). All eight of the people who directly evacuated from offices or schools to shelters traveled with their colleagues or classmates. This suggests that people hesitated to evacuate by themselves.

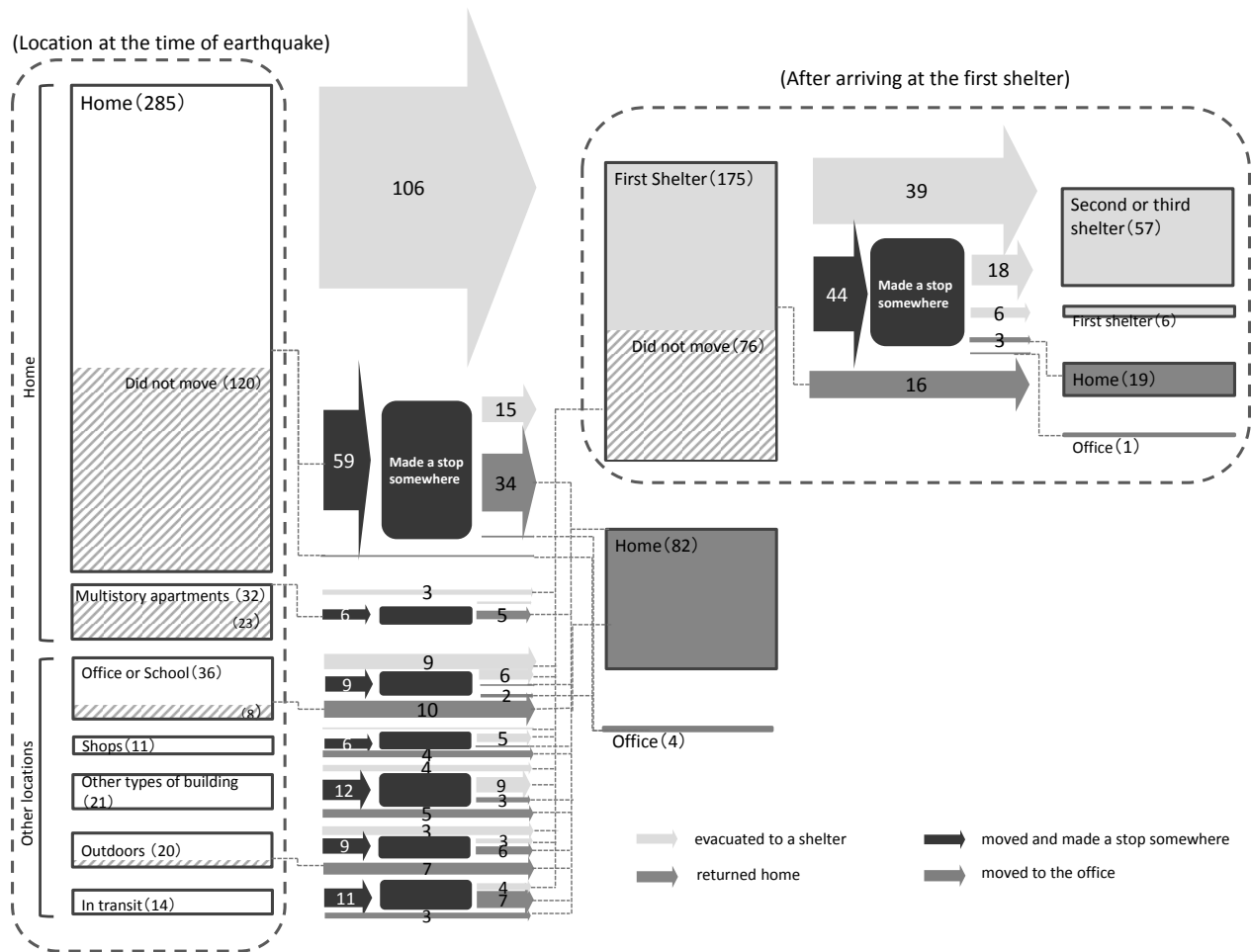


Figure 9 Behavior patterns after the earthquake (N=419)
The size of each square denotes the number of people.

All 11 residents who were in shops left the premises. Five stopped at their homes before evacuating, and the other four returned home and stayed there. One person left a supermarket and evacuated to higher ground using a car, but returned home one time 30 minutes after initially evacuating. Thus, all persons who were shopping returned home once.

The 12 of 21 persons who were inside other types of buildings stopped somewhere else first, then nine of them moved to a shelter while the other three returned home.

As for the residents who were outdoors or in transit,

evacuation rates were lower than for other locations: only 6 of 20 and 4 of 14, respectively. Although this might be due to not receiving the tsunami warning or being aware of its details, as described earlier, lower perceptions of earthquake-induced shaking may also have influenced their behaviors.

(2) Behavior patterns after arriving at the first shelter

The upper right side of Figure 9 shows residents' evacuation behavior patterns after arriving at the first shelter. Over 30% of the 175 evacuees moved to a second or even third shelter. Thirty percent of them stopped at their homes or at a relative's house on the way to the next shelter. In addition, nearly 10% of evacuees individually decided to leave the shelter and return home by about 6:00 p.m.

Table 1 Residents' stopping locations after leaving their original locations

types	starting location	
	home	other location
stop at home	—	27
go to the coast to observe the sea	24	4
pick up their children or grandchildren	15	6
go shopping	9	5
go to a relative's house	5	2
go to the river to observe the tsunami	5	0
go to the fishing port to anchor a boat	4	0
search for someone	2	2

5. FACTORS INFLUENCING EVACUATION-RELATED DECISIONS

5.1 Timing and location of decision-making

Generally, when a disaster occurs, it is necessary for a person to redefine the situation, in other words, to switch

from normal to emergency modes of behavior in order to behave appropriately (Ohno, 2007). To examine this redefinition, we asked all respondents when they recognized that an emergency situation existed.

Figure 10(a) shows the timing of the redefinition made by the persons who evacuated. The vertical axis roughly represents time sequence. More than half of the respondents recognized the emergency when they felt the earthquake or when they heard the meteorological agency's announcement that upgraded the alert to a large-scale tsunami warning. When the first tsunami warning was heard, only 11% of the residents recognized that something unusual had occurred. This result may be explained by the "normalcy bias," the tendency to underestimate an event even though extremely hazardous conditions may be present.

Figure 10(b) shows the time course of evacuees' evacuation-related decision-making. As can be seen in comparison with Figure 10(a), decisions related to evacuation tended to occur later than redefinitions of the situation. More than 30% of the evacuees decided to evacuate when they heard that the initial alert had been upgraded to a large-scale tsunami warning. Some evacuees decided to evacuate when they received a warning by family members or acquaintances, or when they noticed that neighbors had started to evacuate. Interestingly, almost all respondents who redefined the situation as a result of information provided directly and personally by others were able to make earlier decisions.

Figure 11 shows the locations where residents redefined

the situation and then decided to evacuate. Most residents who were in their homes at the time of the earthquake made both determinations in their homes, while many residents who were outside their homes could not make both decisions on the spot. This suggests that one reason that many people returned home was to gather further information since they hesitated to make decisions while alone.

5.2 Reasons for not evacuating

Although the timing varied, nearly 90% of the respondents who did not evacuate recognized the situation as an emergency. Figure 12 shows what make them redefined the situation.

The reasons respondents did not evacuate after the earthquake are shown in Figure 13. The major reason was that they were already in a high altitude location (34%), followed by a belief that the tsunami would not reach them (28%), and the fact that they were not near the sea (20%).

The reasons for not evacuating were related to respondents' locations. As shown in Figure 14, most of the residents who lived in apartments did not evacuate because they lived in multistory apartments. As for respondents who were in their offices, the most frequent answer was "I was at work." It is interesting to note that the social norm that compels individuals to continue working carried more weight than other physical reasons such as altitude or distance from the sea.

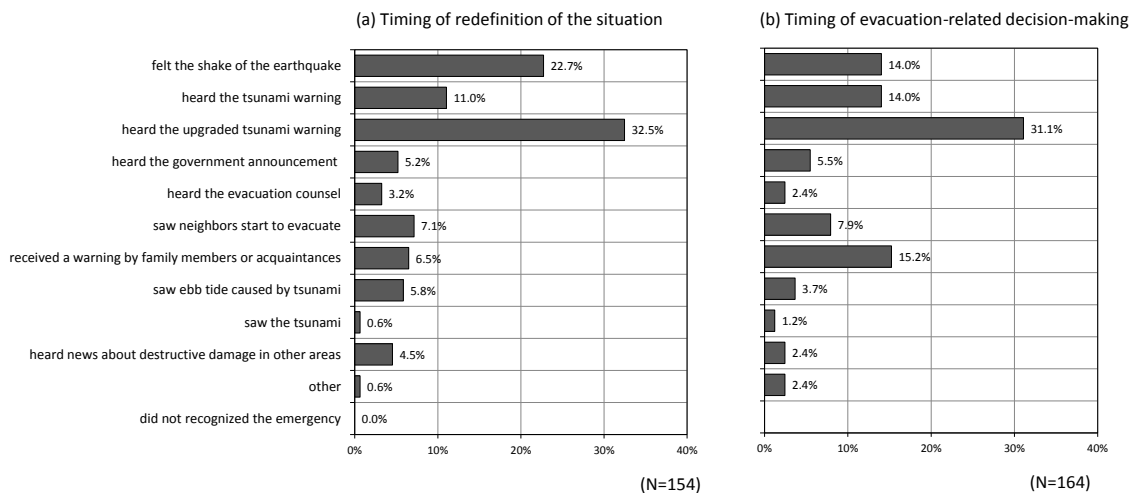


Figure 10 Timing of redefinition of the situation and evacuation-related decision-making by the respondents who evacuated

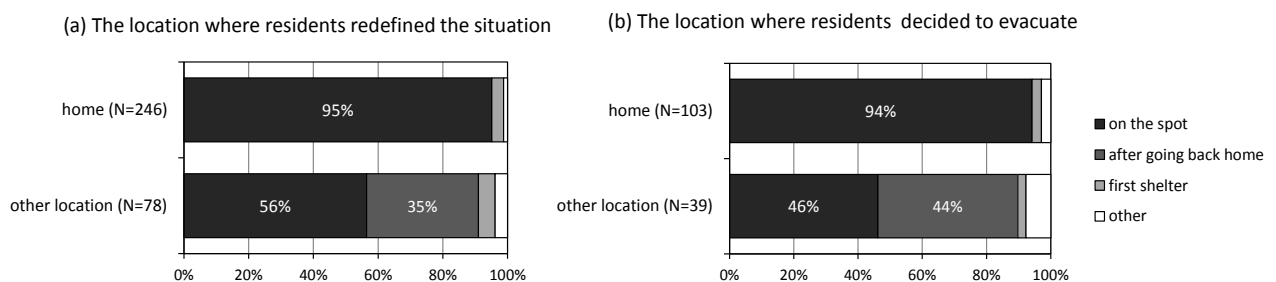


Figure 11 Locations where residents redefined the situation and decided to evacuate

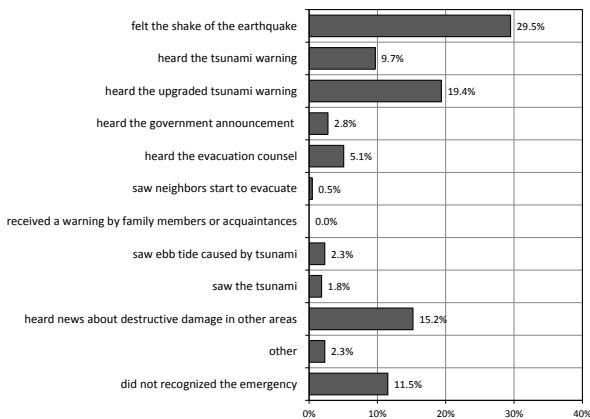


Figure 12 Timing of redefinition by the respondents who did not evacuate (N=217)

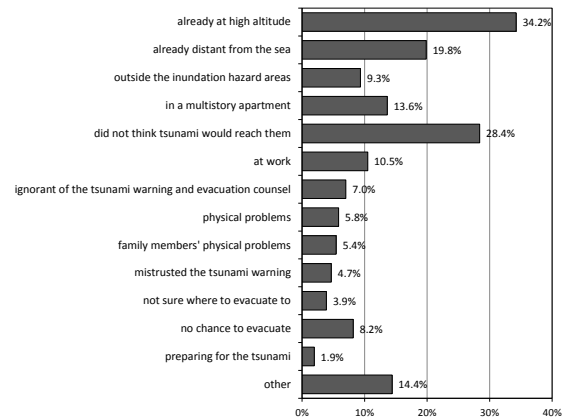


Figure 13 Reasons for not evacuating (multiple answers per individual, N=257)

6. CHOICE OF SHELTERS AND EVACUATION ROUTES

6.1 Types of shelters

Figure 15 shows respondents' initial evacuation destinations. In total, more than 60% of the evacuees selected designated shelters. About 30% of evacuees chose temporary evacuation sites such as high altitude areas, and 17% chose schools or gymnasiums, both of which were designated by the local government on the hazard map. Given the magnitude of the threat posed by this tsunami, the local government provided two additional evacuation shelters. About 16% went to these shelters.

Nearly 40% of the evacuees chose undesigned locations. Some of them evacuated to public facilities (8%), height altitude areas (15%), or houses of relatives or acquaintances (7%).

6.2 Reasons for choosing evacuation destinations

As Figure 16 shows, the most frequent reason for the choice of evacuation site was high altitude (59%). About 27% of respondents chose the shelters because they were designated by the local government, and 24% chose locations that were familiar to them.

Figure 17 shows the factors that evacuees considered when they chose their evacuation routes. The principal characteristics of these routes were that they led evacuees to higher altitudes (67%), led them away from the sea (47%), and required only short travel distances (34%).

Figure 18 shows whether residents evacuated initially to the same shelters they had decided on in their pre-earthquake planning. Forty-seven percent of evacuees traveled to the shelters they had decided on beforehand. Another 14% had planned on an evacuation site but in fact traveled elsewhere, and 39% had not decided where to evacuate. These proportions differed only minimally depending on whether respondents were in their homes or in other locations at the time of the earthquake. These shelter choices are thought to be caused long-distance traveling.

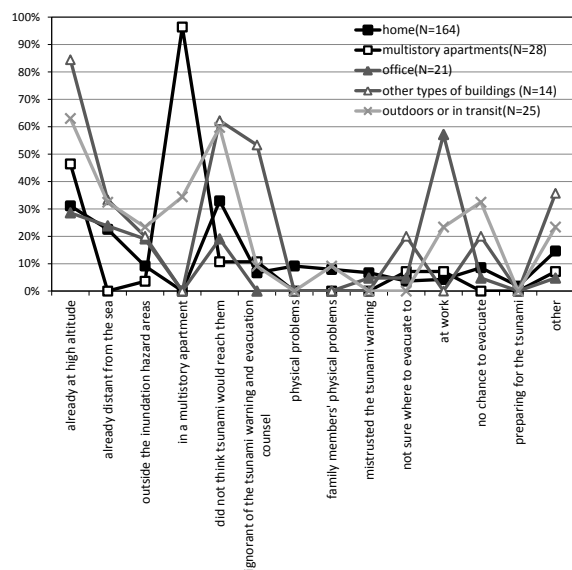


Figure 14 Varying reasons for not evacuating according to location (multiple answers per individual)

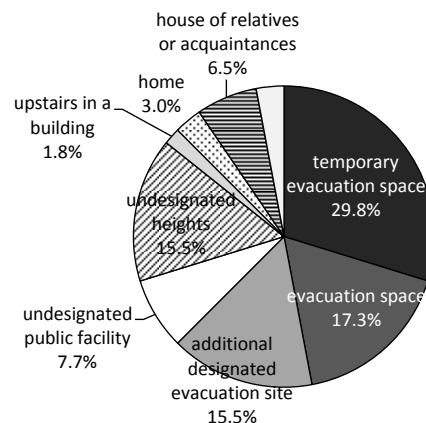


Figure 15 Location chosen as first shelter (N=168)

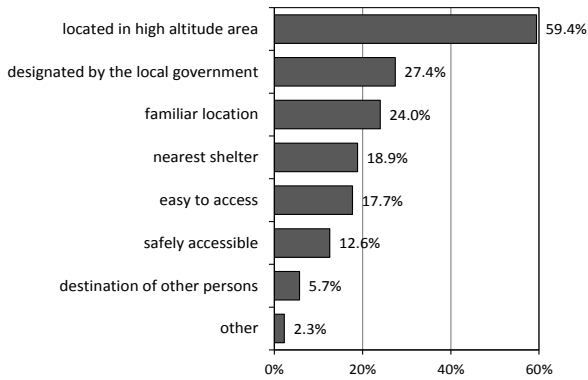


Figure 16 Reasons for choosing the place as a shelter (N=175)

7. CONCLUSIONS

This study investigated the behaviors of coastal residents after the Great East Japan Earthquake of 2011, and discusses the factors influencing their decision-making and route choices.

In spite of the large-scale tsunami warning and the evacuation order, the rate of evacuations to shelters was not high. However, large numbers of residents who did not evacuate to a shelter did in fact leave their original locations. This suggests that we should consider not only direct evacuations to shelters but also other travel activities when we discuss or simulate human behavior during tsunamis.

Residents' behavior patterns differed widely according to their locations at the time of the earthquake. Compared with residents who were in their homes, those outside their homes were less likely to travel directly to shelters. The evacuation rates of residents who were outdoors or in transit were lower than those of other residents.

After the earthquake, residents initially stopped at various locations such as their homes, schools or kindergarten to pick up their children, or the waterfront to observe the sea. Even after they first arrived at a shelter, they again returned to their homes or visited relatives' house. Although in most cases residents sought to get proper information for decision-making or to save family members, these behaviors nonetheless were potentially very risky. Large earthquakes and tsunamis might occur at any time. Therefore, residents must imagine concretely how they will respond to such situations whether in or outside their homes. In particular, we must discuss beforehand potential approaches to ensuring workers' safety, since given the Japanese work climate, workers tend to continue working even in hazardous situations.

Most of the residents who did not evacuate still realized that something unusual had happened. Although some did not receive the tsunami warning (especially those who were outdoors or in transit), the majority could easily have obtained information about the disaster via television, the local government announcement, or observation of the sea, yet they still failed to evacuate. Based on the present study, one of the most important issues involved in planning for

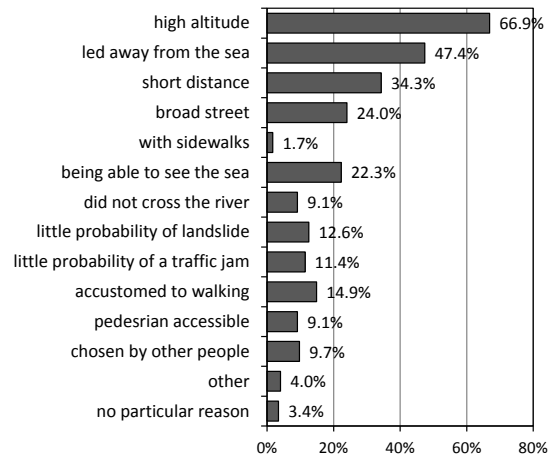


Figure 17 Reasons for evacuation route choices (N=175)

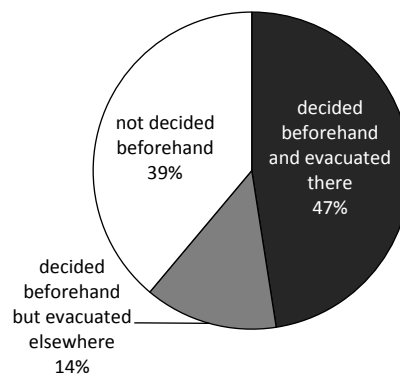


Figure 18 Relationship between the actual choice of first evacuation site and planned location before the earthquake (N=175)

tsunami evacuations is that of decision-making. It is a subjective and irrational belief that a tsunami will not endanger oneself. This attitude is typical of "normalcy bias." Related to this, the present study also suggested that those close to a person can exert a strong influence on their behavior. Thus, when a person hesitates to make decision, external persuasion can prove to be a powerful force that can overcome this bias.

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