An analysis of the circumstances of death in the 2011 Great East Japan Earthquake

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SUMMARY:
Based on the casualty reports of the Fire and Disaster Management Agency of Japan and the police of Iwate, Miyagi and Fukushima prefectures, the authors clarified the circumstances of death and the age-specific mortality associated with the Great East Japan Earthquake of 2011. In the Fukushima prefecture, the authors employed the longitudinal and latitudinal data of residence addresses, thus illuminating the circumstances of victims at the time of death in inundation and washed-away areas. As a result, the relationship of inundation conditions and death was elucidated: the death rates in washed-away areas were obviously high and especially those of the over 70 age-classes.

Keywords: The 2011 Great East Japan Earthquake and Tsunami, death toll, washed-away area, inundation area

1. INTRODUCTION

The Great East Japan Earthquake of March 11, 2011 caused massive devastation in Japan: 16,146 people died; 3,333 were missing, 126,491 houses completely collapsed (about 78,000 were washed away), and 227,600 more were partially destroyed (FDMA: Fire and Disaster Management Agency [2011A] and City Bureau, MLIT: Ministry of Land, Infrastructure, Transport and Tourism [2011]). Most of this damage was caused by the tsunami induced by the earthquake; three prefectures—Iwate, Miyagi, and Fukushima—of the Tohoku (North-Eastern) Region of Japan were especially hard hit.

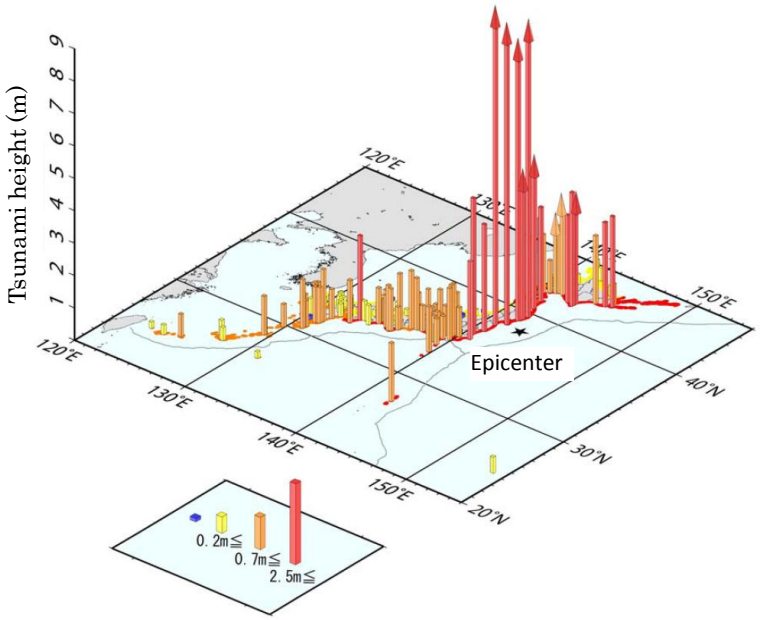

Figure 1. Tsunami height map (JMA [2011])

The immense devastation caused by this earthquake and tsunami has forced Japan to reconstruct its defenses against tsunamis. Figure 1 is a map of the tsunami's height based on data of the Japan Meteorological Agency (JMA: Japan Meteorological Agency [2011]). It indicates that high tsunami heights are mostly located in the Tohoku region of Japan.

This paper reviews the circumstances of victims at the time of death in the Iwate, Miyagi, and Fukushima prefectures and presents a detailed analysis of mortality in the tsunami inundation areas.

2. METHODS

The casualty data used in this study are collected from the situation reports of the FDMA (FDMA Situation Reports Nos. 2 to 142 [2011B]) that indicate damage and loss and the body-identification information of the Iwate, Miyagi and Fukushima prefectural police that was announced by December 28, 2011. With regard to these data, the authors note that the number of deaths announced by the police might not exactly correspond to the number of all identified victims, since information is in some cases classified out of respect for the wishes of the families of those who died.

The FDMA situation reports include information on casualties, such as the numbers of dead, injured, and missing people and the numbers of fully or partially collapsed and damaged buildings. The data, which were issued over time, are collected by the fire departments of each municipality. The body identification information of the prefectural police generally includes the names, ages, and residential zones of the deceased. For the Fukushima prefecture, we obtained detailed residence addresses.

The run-up areas of the tsunami (hereafter, referred to as "inundation areas") and the damaged areas where most houses were lost (hereafter, referred to as "washed-away areas") are based on the Tsunami Damage Mapping Team [2011] "Maps of the Areas hit by the Tsunami of 11 March 2011." Figure 2 shows the inundation areas and washed-away areas of the three prefectures that are the targets of this study.

As for the time-series transition data of the deceased and the missing, we used the situation reports of the FDMA, and for the residence addresses, genders, and ages of the deceased, we employed the data announced by the prefectural police. In the Fukushima prefecture, we obtained the detailed data of the residence addresses of the deceased, so we overlaid the data on the "Maps of the Area hit by the Tsunami of 11 March 2011" (Tsunami Damage Mapping Team [2011]) and analyzed the locations of victims at the time of death in the inundation and washed-away areas. We analyzed the data using the statistical package R version 2.15.0 (www.r-project.org/).

3. RESULTS

3.1. The trend of reported deaths

Figure 3 shows the trend in the number of deaths reported by the FDMA (Situation Reports Nos.2 to 142 [2011B]).

In the Great East Japan Earthquake, casualties, including the deceased and missing, reached the enormous number of about 20,000; thus, the search for bodies became a long-term operation. From Figure 3, we can see that it took about two months to identify the 90% of the victims found by 12 December 2011.

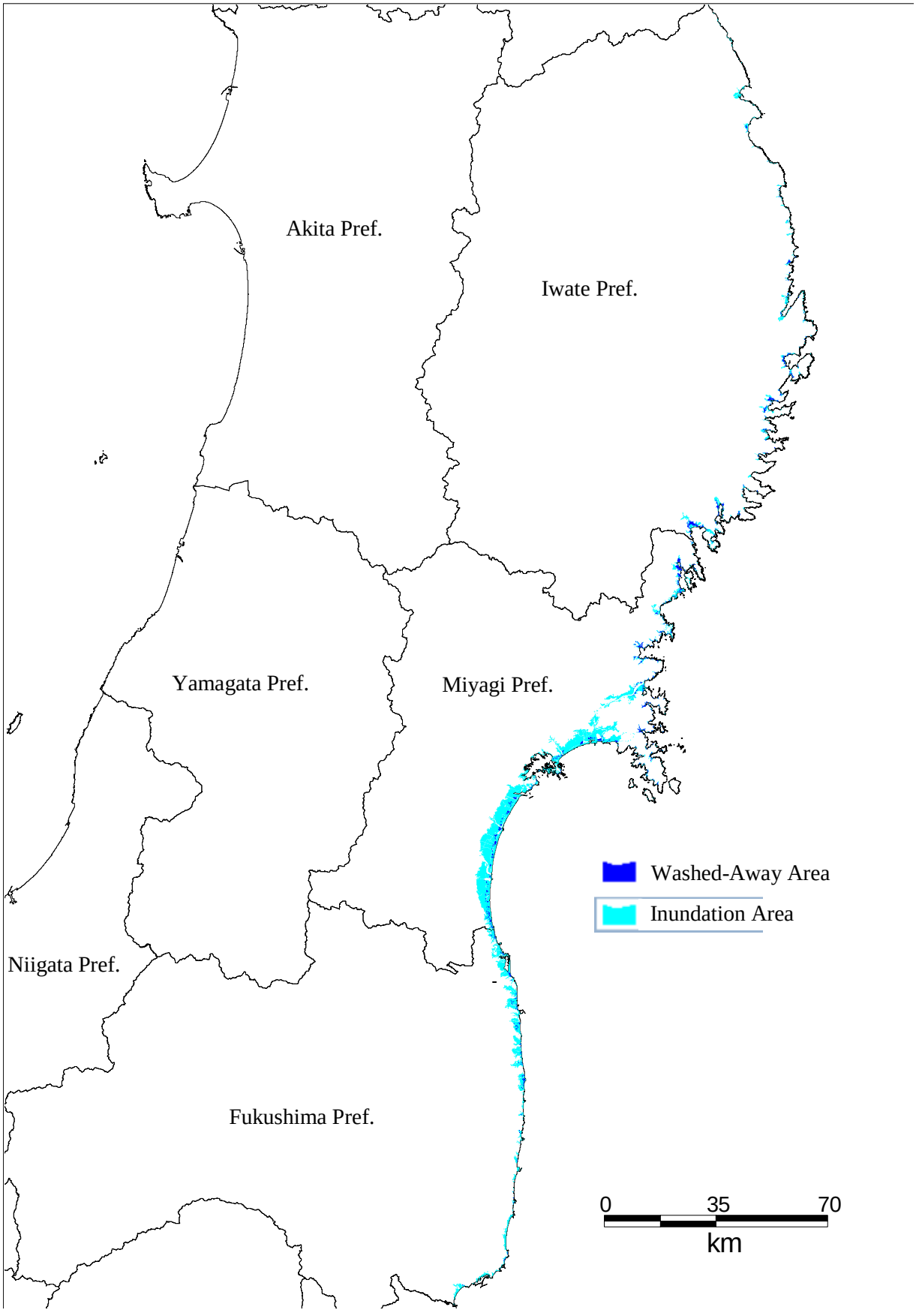

Figure 2. Tsunami inundation and washed-away areas (Tsunami Damage Mapping Team [2011])

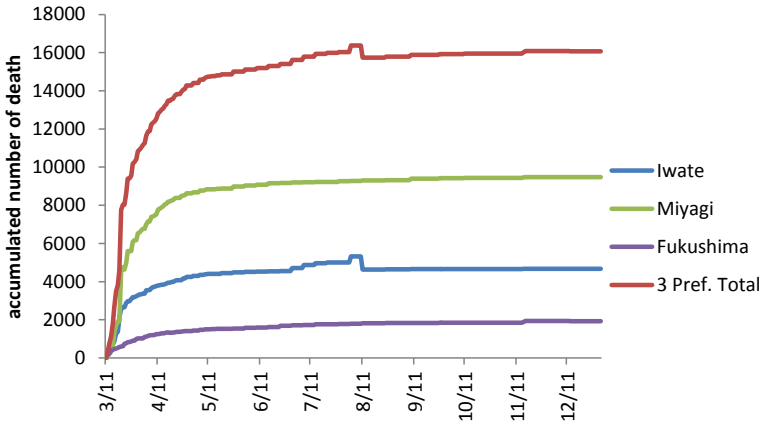

Figure 3. Trend of reported deaths by the FDMA (the number of bodies found)

Figure 4 shows the trend in the number of identified bodies announced by the police of the prefectures of Iwate, Miyagi, and Fukushima (hereafter, referred to as "the three prefectures"). From this figure, it can be seen that 90% of the identifications of 12 December 2011 had been made approximately three months after the disaster. Comparing Figure 3 and Figure 4, the one-month difference between these two data sets indicates something of the difficult time-consuming process of finding and identifying bodies.

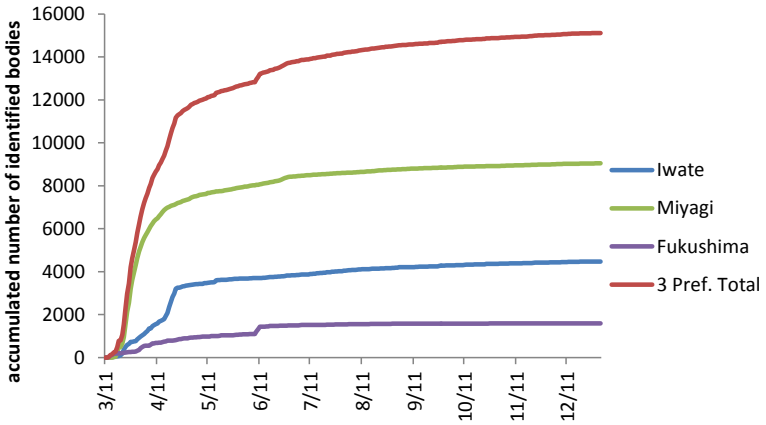

Figure 4. Trend of identified bodies reported by the prefectural police

Figure 5 shows the difference between the number of deaths announced by the FDMA (the number of bodies found) and the number of bodies identified by the police of the three prefectures. A precise study of these two sets of data is difficult because information on some identified bodies are excluded in accordance with the wishes of families; however, it can be seen that about 2,000 bodies were still not identified nine months after the earthquake.

In the case of the tsunami, many bodies were found in places other than those actually hit by the great waves (e.g., homes), and many bodies were terribly damaged. This is a particular feature of the tsunami disaster.

Figure 6 shows the trend of the numbers of dead and missing people. Among the latter, various types of cases are mixed, including those who had escaped to regions far from their home towns and whose whereabouts were unknown to municipal government, those had moved or died before the earthquake without revising their resident registration information, and those who died in the earthquake itself but whose bodies were not found.

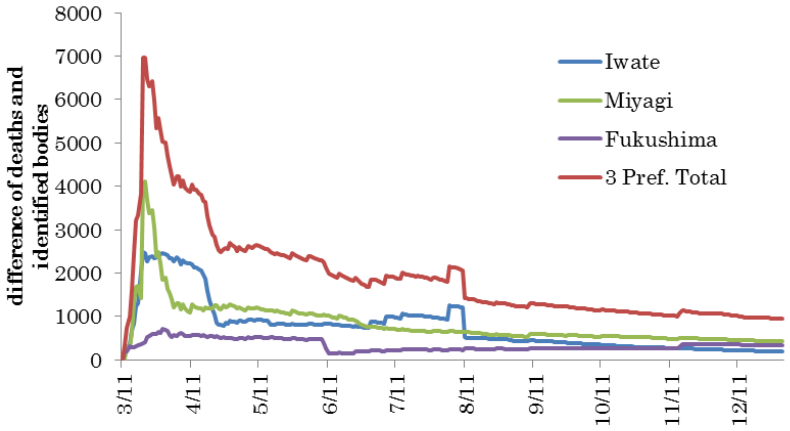

Figure 5. Trend in the difference of found and identified bodies

The search for missing people involved the painstaking verification of their residence registrations; over time, this procedure resulted in a reduction in the number of those deemed to be missing and a rise in the number of those declared to be dead. Figure 6 indicates that the confirmation process for missing people did not make much progress for about a month after the earthquake but gradually improved thereafter.

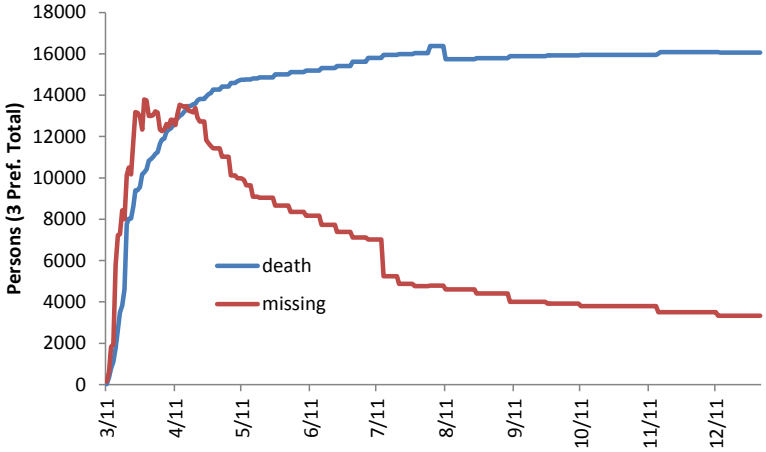

Figure 6. Trend of the number of death and missing

3.2. Gender and age distribution of the deceased

According to the 2005 national census (hereafter, simply "census"), the gender ratio of the three prefectures was 48% male to 52% female, while that of the deceased announced by the police was 47% male to 53% female. Figure 7 shows the population distribution by gender and age class from the census data in the 500 grids included in the inundation areas shown in Figure 2. Figure 8 displays the gender and age-class distribution of identified bodies. Figure 9 shows the death rates by gender and age class that are calculated from the above. It demonstrates that the death rates of those in the over 60 age classes are sharply higher. Furthermore, as age increase, the death rate of males increases. This result may be explained by the fact that the average life span of males is shorter than that of females; consequently, we ran a Cochran-Mantel-Haenszel test to determine if the death rates are related to gender in various age classes. We found a significant difference in the relationship of the gender and death ratios of males and females.

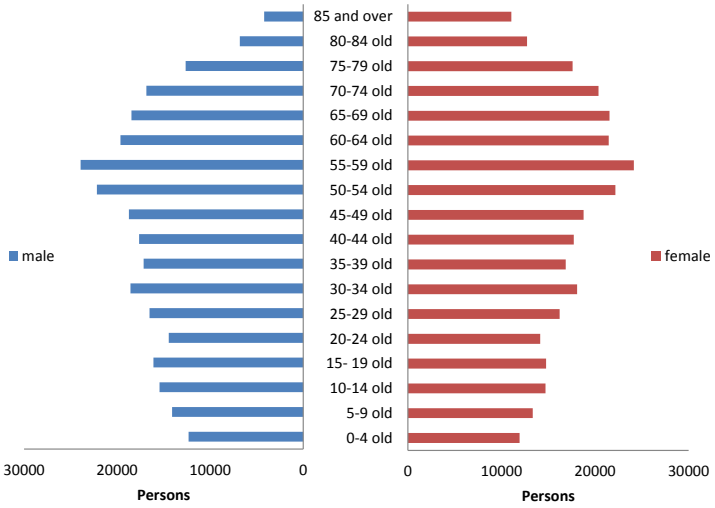

Figure 7. Population pyramid in inundation areas

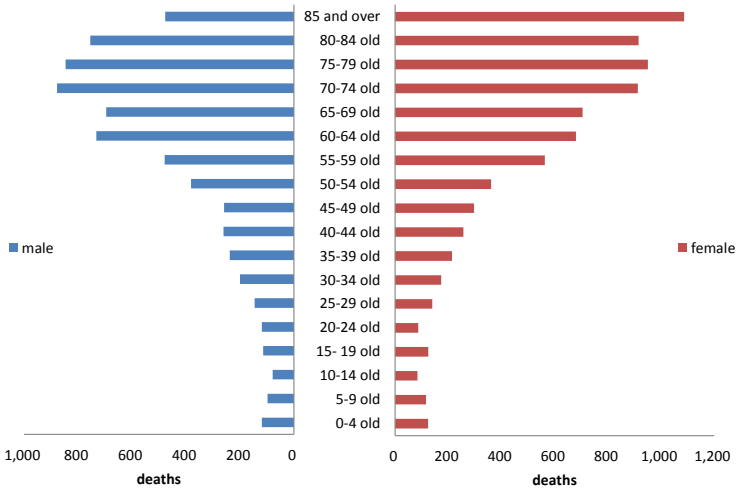

Figure 8. Age pyramid of deaths

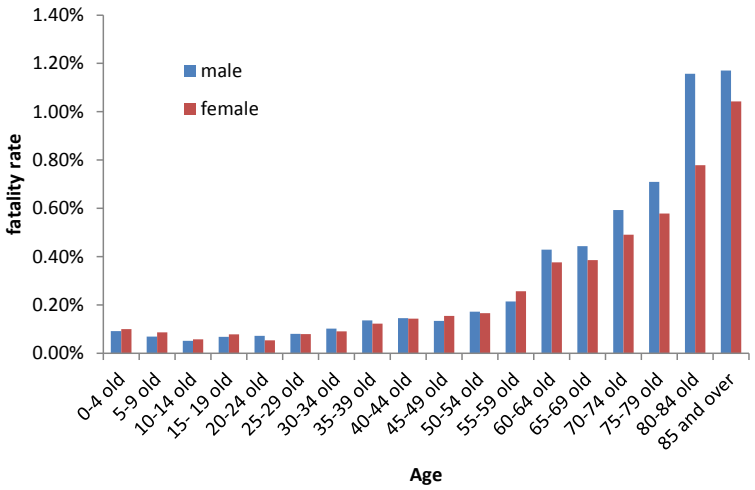

Figure 9. Fatality rate by age and gender

3.3. Situations of death in the Fukushima prefecture

For the deaths in the Fukushima prefecture, there are 1,590 pieces of data on residence locations at the time of the tsunami. Using the maps of the area hit by the tsunami of the Association of Japanese Geographers [2011], we studied the relationship between these locations and inundation/washed-away areas. The places of death and residence addresses do not coincide; however, since in many cases it is impossible to determine the place of death by the tsunami, we used the longitude and latitude data of residence addresses as the location data and compared them with different inundation conditions.

Figure 10 shows the inundation and washed-away areas and the longitude and latitude data of the residence addresses of the deceased at the time of this disaster. The deaths were caused not only by the tsunami; thus, they occurred in wide areas of the Fukushima prefecture. However, most remarkably, deaths are concentrated in costal inundation areas of the tsunami. Figure 11 displays a close-up of this relationship. This figure clearly shows that the most of the deaths occurred in the washed-away areas, where many of the houses were lost.

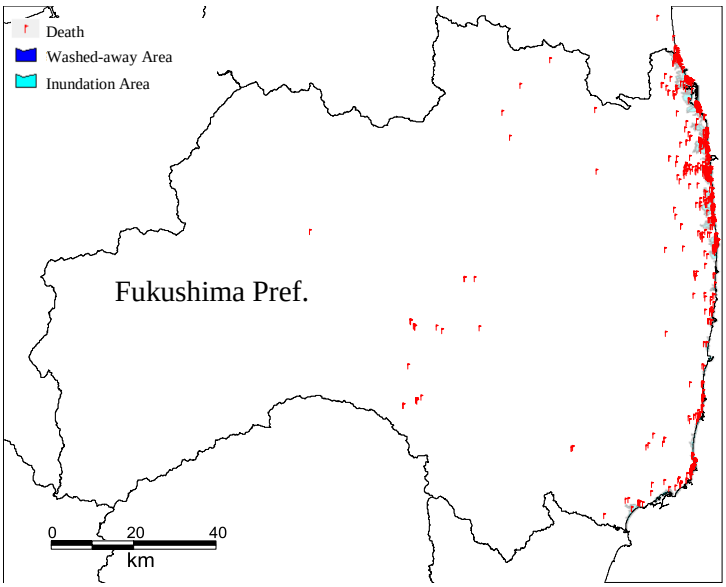

Figure 10. Spatial distribution of death in the Fukushima prefecture

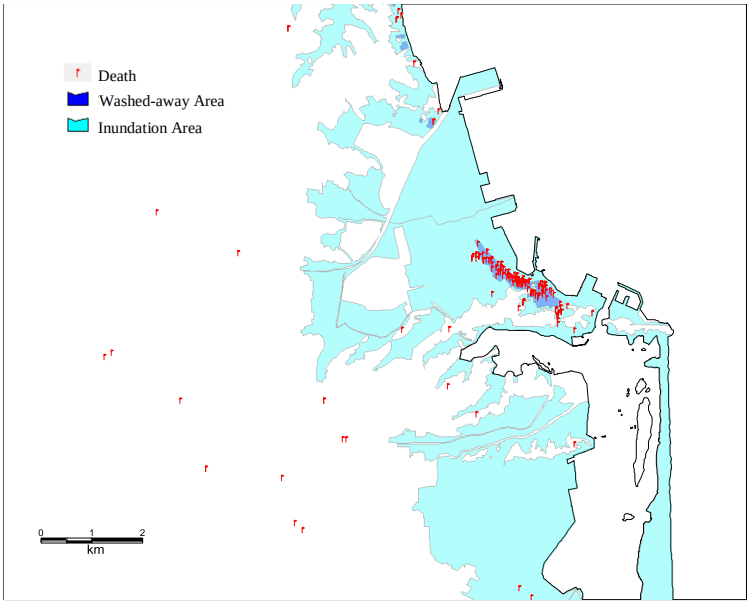

Figure 11. Spatial distribution of death in a close-up

In order to examine the relationship between the conditions of inundation and deaths, we calculated the death ratio using the 500 meter grid population data of the census of inundation and washed-away areas. We found that the death rate in the grids, including the inundation areas, were 1.58 %, while that of washed-away areas was 12.1 %. Furthermore, the death rate in inundation areas, excluding the washed-away areas, was 0.16 %. This last result is consistent with the situation seen in Figure 11 in that deaths are concentrated in the washed-away areas.

Figure 12 displays the age-classified results of the death rates in 500 meter grids in inundation and washed- away areas. The death rate in washed-away areas was found to be high, even in the young age class of those in their 20s, which was 2%. More remarkable, the death rates in the age classes of those over 60 were exceptionally high: it was 10 to 13% for those in their 60s and 70s and 18% for those older than 80.

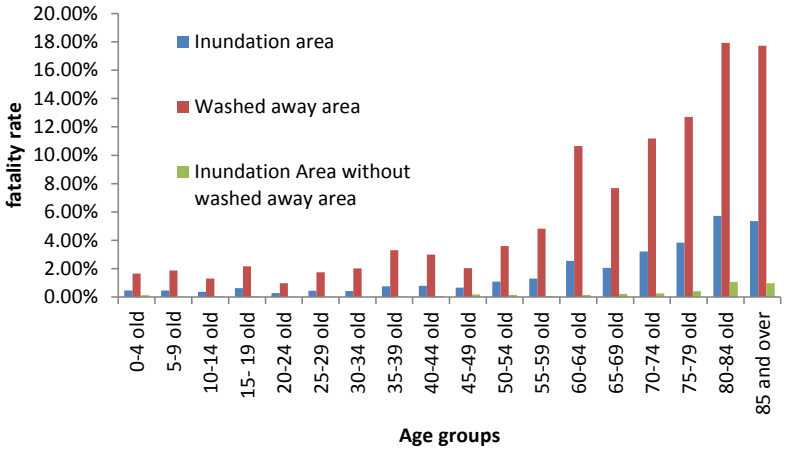

Figure 12. Fatality rate of inundation situation (Fukushima prefecture)

In order to study the casualty impact of the tsunami, it is necessary to compare death rate and inundation depth data; however, we do not yet have the spatial observation data of the latter. Therefore, the authors used available altitude data that represent one of the parameter of inundation depths and compared them to the location data of the resident addresses of the deceased. For the altitude data, we used the 10 meter grid digital elevation model of the Fundamental Geospatial Data developed by GSI-Japan (Geospatial Information Authority of Japan [2011]).

Here it is not appropriate to compare points outside of the inundation areas, so Figure 13 shows the altitude distribution of the inundation areas, washed-away areas, and inundation areas exclusive of washed-away areas for the 1,358 residence address locations (points). It can be seen that many deaths occurred at altitudes less than 11 meters, and especially of less than 6 meters.

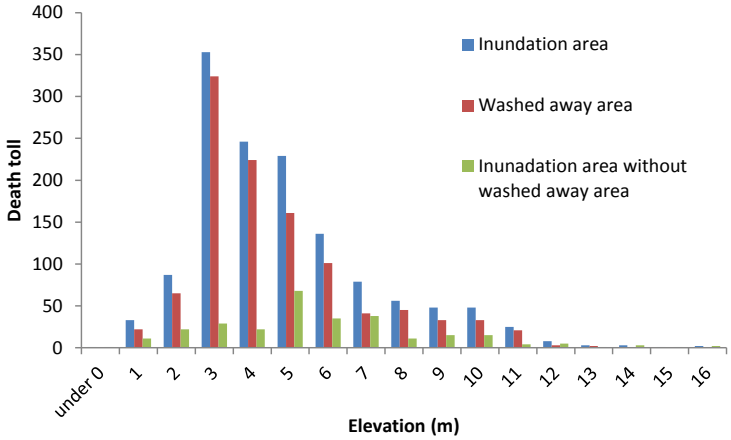

Figure 13. Death toll by inundation situation (Fukushima prefecture)

4. DISCUSSION

4.1. Time-series trend of the number of deaths

Generally speaking, the bigger a disaster, the more time needed to grasp the complete picture of the damage produced by it. In the Great East Japan Earthquake, the tsunami caused many deaths and created so much devastation that it took as long as several months to find and identify bodies. Those involved in this process encountered multiple difficulties, such as the displacement of bodies offshore by the tsunami's strong drawback; the loss of vital administrative documents and data, including residence registration data from impacted city and town halls; the deaths of many administrative officers; and the inability of easily communicating information on severely damaged telephone and other communication networks.

In Fukushima prefecture, the fact that the 20 km radius area around the Daiichi nuclear plant had been designated as an evacuation zone made it even harder to find bodies. We studied the time-series trends of deaths by prefectures and found that the situation caused by the tsunami differs in cities and towns, depending on whether these were in washed-away areas or inundated, but not severely damaged areas.

4.2. Gender and age-class distribution of the deceased

As seen in the death rates of the three prefectures (Figure 9) and in the age-classified death rates of inundation and washed-away areas in the Fukushima prefecture (Figure 12), the number of deaths and the death rates of elderly people were much higher than those of other age classes.

According to the 2007 White Paper on the National Lifestyle (Cabinet Office [2007]), over 60% of fulltime housewives but only around 10% of working people are at home around 14:00 on weekdays. Most people over 60 are retired and may have difficulty in engaging in tasks or leisure activities outside of their places of residence, since their mental and physical functions have declined with age; thus, the proportion of elderly people who were at home at the time of the earthquake and tsunami is thought to be higher than that of fulltime housewives. The high proportion of elderly people at home and their reduced mental and physical functions are assumed to be the major causes of the high death rate of this group.

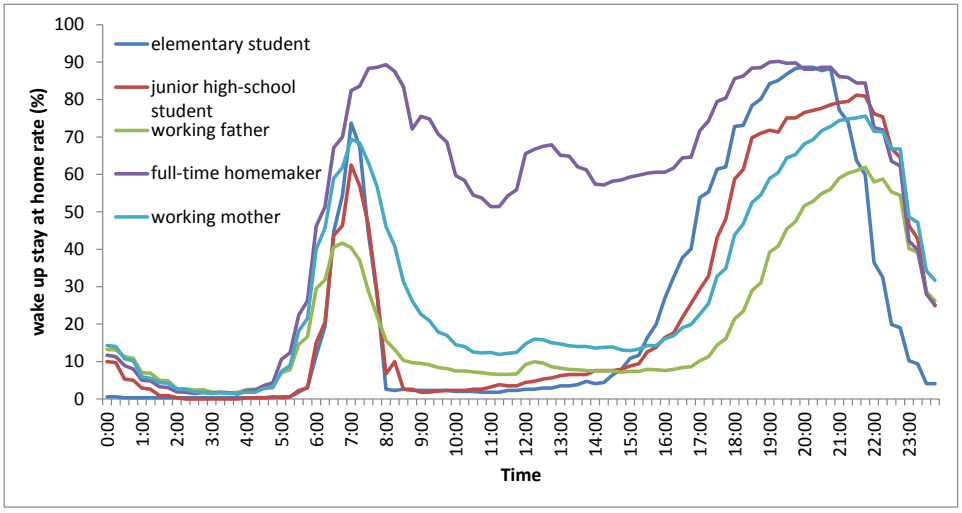

Figure 14. Wake-up stay-at-home rates (Cabinet Office, Government of Japan [2007])

4.3. Deaths in the Fukushima prefecture

By comparing the longitude and latitude data of the residence addresses of the deceased and the geographical data on inundation areas and the washed-away areas of the tsunami, the authors demonstrate that mortality was determined by the loss of most houses in an area and not by inundation alone. Based on a survey made by the Ministry of Land, Infrastructure, Transport, and Tourism [2011], more than 50 % of houses and buildings in washed-away areas were lost when the inundation depth exceeded 3.5 meters. This is consistent with Figure 13, which demonstrates that the number of deaths and rate of death rise sharply with an altitude of less than 6 meters. However, many areas of less than 6 meters altitude did not wash-away. In order to make damage predictions in future disasters, it is essential to explain this disparity.

5. CONCLUSION

In this paper, we studied the data on death and body identification in the Iwate, Miyagi and Fukushima prefectures that suffered enormous damage in the Great East Japan Earthquake, clarifying trends over time. Taking the Fukushima prefecture as a subject, we specified the longitudinal and latitudinal data of the resident addresses of the deceased; we clarified the relationship between inundation/washed-away areas and the situations in which death occurred. In particular, from the age-classified death rates, we addressed the issue of elderly mortality.

In this study, we used pubic data; therefore, other important information that is directly relevant to the fate of victims could not be considered, including spatial inundation depths, the location of people at the time of the tsunami's arrival, and the construction dates, structures, and number of floors of buildings. If this information becomes available in the future, a more concrete analysis can be made, the findings of which would be of great benefit in taking preventive measures for future disasters. It is said and we ardently hope that future disclosures of parts of these data will occur.

ACKNOWLEDGEMENT

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