Transition of Housing Location in the Damaged Coastal Areas before the 2011 Great East Japan Earthquake

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LISBOA 2012

SUMMARY:
Before the 2011 Great East Japan Earthquake, the authors examined the transition of housing location in the damaged areas in Iwate Prefecture due to the 1896 and 1933 Sanriku Tsunamis. Firstly this paper clarifies that the relocation to higher lands after the 1896 Tsunami decreased the damage by the 1933 Tsunami in some districts, and the other areas that failed to relocate experienced severe damage again. Secondly, focusing on seven districts (Taro, Ryoishi, Katagishi, Kojirahama, Hongo, Kerobe, and Urahama), it demonstrates that the houses had gradually increased since 1934 in the building construction restricted areas by the 1934 Post-Tsunami Recovery Plan, using aerial chronological photos provided by Geospatial Information Authority of Japan. Then the reasons why residents started living in the coastal areas are clarified along with residents' tsunami risk recognition based on interview surveys. Finally it refers to the damage situation in the seven districts due to the 2011 Great East Japan Earthquake and Tsunami.

Keywords: tsunami, 2011 Great East Japan Earthquake, post-tsunami urban recovery, relocation to higher land

1. INTRODUCTION

Housing relocation from the damaged coastal zone to higher lands is one of the most definite post-tsunami strategies to avoid future tsunami danger. Therefore that basic strategy was applied in post-tsunami urban recovery plans in many tsunami-experienced countries such as Papua New Guinea after the 1988 Tsunami, Indonesia, and Sri Lanka after the 2004 Indian Ocean Tsunami. However, it seems difficult to keep the resettlement condition for a long time. How was the housing location changed after tsunamis? Why did people return to the coastal areas? With those questions, this paper focuses on long-term change of housing location in the Sanriku Rias Coastal Areas in Iwate prefecture, which were repeatedly damaged by the previous tsunamis as well as the 2011 Great East Japan Earthquake and Tsunami.

1.1. Problems of Post-Tsunami Resettlement

Although the housing relocation to higher lands is an efficient post-tsunami recovery strategy, it has a problem: the inhabitants sometimes return to the original coastal sites for some reasons. For example, the victims affected by the 1992 Tsunami to Flores Island in Indonesia were forced to relocate, but most people except who did not have a land at original location returned to the original site to live in within a few years because of difficult adaptability to the new environment (Maki et al., 2003). Also, Nakazato et al. (2009) clarifies that some people in a coastal area in Banda Aceh affected by the 2004 Indian Ocean Tsunami intended to stay in the original location because of an occupational reason and familiarity with the site.

1.2. Research Object

Surrounded by the ocean, Japanese people have experienced several great tsunamis since before the

2011 Great East Japan Earthquake and Tsunami (CAO, 2007). Especially the Sanriku Coastal Areas, mainly Iwate and Miyagi Prefecture, were devastated four times for the period. The 1896 Meiji-Sanriku Tsunami killed 21,959 people, and the 1933 Showa-Sanriku Tsunami attacked almost same areas to claim 3,064 lives. In 1960, the Chilean Tsunami came to the areas twenty-two hours after the earthquake occurred in Valdivia, Chile, and 142 people died. The latest and the greatest tsunami occurred on March 11, 2011, and its influence on Japanese society is still spreading.

As well as the cases in Flores Island or Banda Aceh, it repeatedly occurred in the tsunami-prone Sanriku Coastal Areas in Japan that relocated people after a tsunami returned to the original location to be hit by the next one. Then it is important to understand vicissitudes of the settlement situation in the areas to consider future tsunami recovery policy. Some Japanese researchers dealt with the matter so far. Miyano and Hayashi (1989) clarified that seriously damaged and bigger villages tended to be relocated to higher lands using tsunami damage data of 1896, 1933, and 1960. Yamagichi (1964) pointed out some problems of post-tsunami housing relocation in the damaged areas due to the tsunamis. Kumagai et al. (1981) clarified that in the relocated areas after the 1933 Tsunami are occupied by the houses constructed before 1945 and in the other areas by newer houses. Then, Mune et al. (1983) explained that the increase of housings in the coastal areas were because of a shortage of residential lands in the higher areas. However, long-term transition of housing location in those areas have not been cleared even though Japanese post-war social situation are dramatically changed.

In order to contribute to future post-tsunami urban recovery plans, this paper examines the long-term situation of post-tsunami housing location in Iwate Prefecture, especially focusing on seven districts, after the tsunamis in 1896 and 1933 using aerial photographs, and clarifies the residents' tsunami risk recognition based on interviews conducted before the 2011 Great East Japan Earthquake and Tsunami.

2. METHOD

The research in the paper pursues the following method. At first, the damage in Iwate Prefecture due to the tsunamis in 1896 and 1933 and those recovery policies are chronologically outlined, and the effect of relocation after the 1896 Tsunami is clarified based on building damage comparison. Secondly, the transition of housing location after 1936 Showa-Sanriku Tsunami in seven districts chosen by the abovementioned analysis is examined using aerial photographs provided by Geospatial Information Authority of Japan (GSI, 2007). The chosen seven districts are (1) Taro, (2) Ryoishi, (3) Katagishi, (4) Koshirahama, (5) Hongo, (6) Kerobe, and (7) Urahama. Finally, the reasons why people are living in the coastal areas and residents' risk recognition of tsunami are clarified based on interviews with 100 residents in the seven districts.

In this connection, each Sanriku Coastal area surrounded by mountains and the ocean, a small community called "shuraku" in Japanese jurisdictionally functioned as a community unit. A village or township consisted of them. We define "shuraku" as "district" in English in this paper.

3. COMPARISON OF THE DAMAGE DUE TO THE 1896 AND 1933 TSUNAMIS AND POST-TSUNAMI RECOVERY POLICIES

Before the 2011 Great East Japan Earthquake and Tsunami, Iwate Prefecture had been hit by the devastating tsunamis twice in 1896 and 1933. Those regional tsunami heights are shown in Figure 3.1 with the after-mentioned research objective districts. Between the tsunamis, the damaged districts conducted post-tsunami recovery plans and realized them respectively. Some of them stayed living in the damaged area; the other relocated settlements to higher lands. However it was difficult for some people to stay in the highland resettlements. The situation influenced the damage conditions due to the 1933 Tsunami. The following are those process of damage and recovery between the two tsunamis.

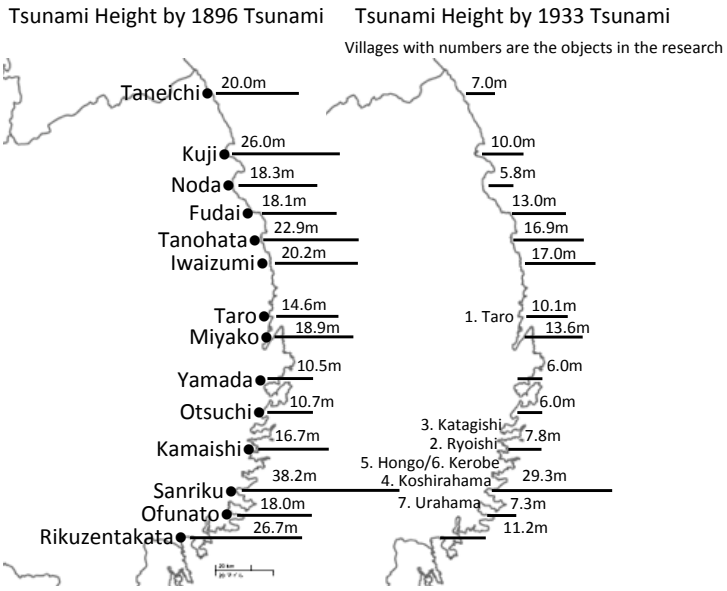

Figure 3.1. Regional Tsunami Height by the Sanriku Tsunamis in 1896 and 1933 (Yamashita, 1982)

3.1. Damage by the 1896 Meiji-Sanriku Tsunami and Post-Tsunami Recovery Policy

The 1896 Meiji-Sanriku Tsunami was the most catastrophic tsunami in Japanese contemporary history. The magnitude 7.1 earthquake with its epicenter lying around 200 km east of Kamaishi occurred at 7:32 on June 15 (local time), 1896 in Japanese Meiji era. It caused tsunamis to the Sanriku Rias Coastal Areas in Iwate and Miyagi prefectures, and they damaged to about 7,000 houses and killed 21,959. Above all, the damage in Iwate Prefecture was 5,617 houses and 18,159 deaths tall (Earthquake Investigation Committee, 1897).

It was a conventional age in which the tsunami mechanism was not clearly understood and local governments did not systematically functioned for post-tsunami recovery. Yamashita (1982) describes that there was no example of habitational relocation led by National or Local Governments, but most of the relocation was conducted individually or habitationally by local powerful landowners.

However, it happened in many districts that relocated people had returned to the original coastal areas by the next one, the 1933 Showa-Sanriku Tsunami. Central Disaster Management Council (2005) points out that "long distance from the relocation site to the coast for fishery," "shortage of drinking water in the higher lands," and "inconvenience of transportation" were reasons of the return.

3.2. Outline of the 1933 Showa-Sanriku Tsunami

The Showa-Sanriku Earthquake and Tsunami of magnitude 8.3 occurred at the east of the 1896 Earthquake epicenter at 2:30 on May 3rd, 1933 in Showa era. It collapsed about 6,000 buildings and killed 3,064 people. The most seriously damaged area was Iwate Prefecture as same as the last one: the number of damaged buildings was 2,713 and the deaths toll was 4,035 (ERI, 1934). Although the event happened around midnight, its casualty was not so heavy compared with the 1896 Tsunami because most of them were able to efficiently evacuate after the shock learning from the previous experiences.

3.3. Comparison of Building Damage Ratio due to the 1896 and 1933 Tsunamis in Terms of Relocation Condition

The building damage in each district depends on the before-mentioned relocation condition.

Hereafter, the building damage due to the 1933 Showa-Sanriku Tsunami is discussed in terms of relocation condition. There are several materials about the damage and recovery conditions related to both the tsunamis. Then, this paper deals with dataset by Usami (2003) for building damage; the reports by Central Disaster Management Council (2005), and Yamaguchi (1972) for the recovery process.

At first, fifty-three coastal districts in Iwate Prefecture are classified in terms of relocation condition after both the tsunamis. Relocation conditions after the 1896 Meiji-Sanriku Tsunami are classified into four categories: (I) recovery on the original site for nine districts, (II) return to the original site after relocation for eleven districts, (III) relocation to higher land without return for ten districts, and (IV) unknown from the literature survey for twenty-three districts.

Secondly, the conditions after the 1933 Showa-Sanriku Tsunami are also sorted into three groups: (a) recovery on the original site for five districts, (b) relocation to designated higher land for fourty-five, and (c) unknown from the literary survey for three districts. That classification is used to choose the focused villages for the following chapter.

Building damage ratio is calculated based on the number of completely damaged buildings and pre-tsunami households. Then, the districts whose number of previous households is unknown in the referred materials are deleted for comparative analysis.

Finally two figures were acquired as a result of the above procedure. Figure 3.2 shows comparison of districts' complete building damage ratio due to the 1896 and 1933 Tsunamis in terms of relocation condition: Left side figure is for (I) recovery on the original site and (II) return to the original site after relocation, and right figure is for (III) relocation to higher land without return. The horizontal axis refers to the damage ratio by the 1933 Tsunami, and the vertical axis represents the ratio by the 1896 Tsunami. Points on the diagonals in both the figures mean that damage level of a district by the 1933 Tsunami was almost same as its previous situation. The more to the left, the more reduced damage respectively. The right side figure shows that the damage ratio of seven relocated districts out of eight is decreased drastically when the 1933 Tsunami. On the other hand, the damage ratio for the districts reconstructed on the original sites (type I or II) is less reduced than that of type III, and especially the damage ratio of the six districts still remains at more than 60% as well as the previous one. That tendency proves an effect of the relocation strategy after the 1896 Meiji-Sanriku Tsunami.

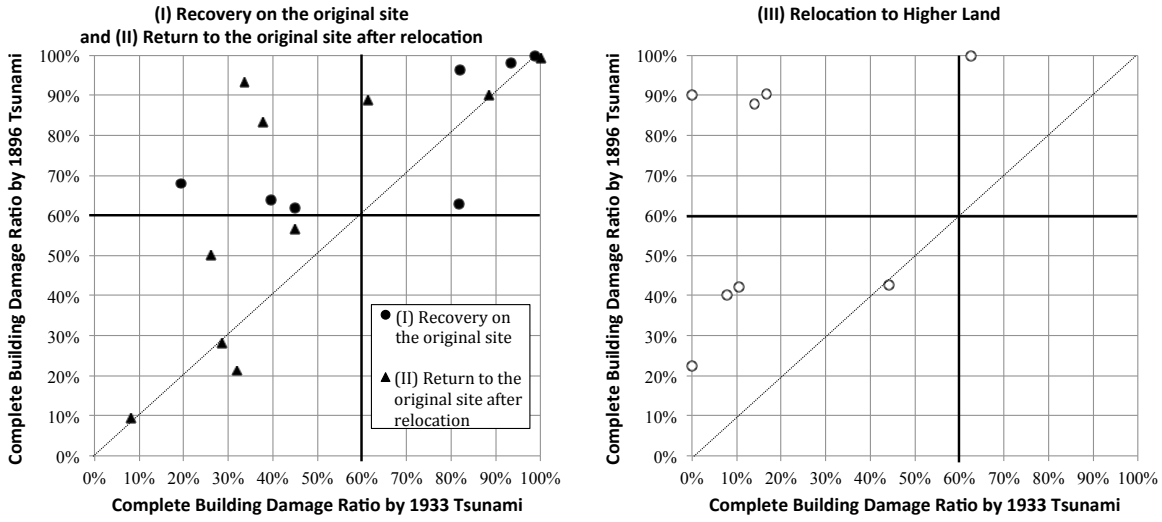

Figure 3.2. Comparison of Districts' Complete Building Damage Ratio due to the 1896 and 1933 Tsunamis in Terms of Relocation Condition

3.4. Outline of Recovery Policy after the 1933 Showa-Sanriku Tsunami

Three months after the 1933 Showa-Sanriku Tsunami, Council for Earthquake Disaster Prevention (1933) issued Advisory Report for Tsunami Disaster Prevention, and the recovery plan of the damaged towns and villages (Prewar Home Ministry, 1934) were released based on the report including basic policies: (1) small districts with slight damage are to be recovered by the victims' own efforts; (2) fair-sized or seriously stricken areas are to be recovered mostly by treasury or low-interest loan supported by National Government; (3) every house for fisherman or farmer in the coastal area is to be relocated to a higher land; and (4) regional hub towns or villages of transportation, economy, or education, five districts of type (a) in Table 3, are to be recovered in the original areas with some tsunami mitigation strategies because it would be difficult to remove all buildings to other places.

As a result, many districts were relocated to higher lands by the government recovery policy. However, the housing location situation had been changed for more than seventy years when the authors investigated in 2010. The situation is clarified in the next chapter.

4. TRANSITION OF HOUSING LOCATION IN SEVEN DISTRICTS

4.1. Selection of the Objective Districts

This chapter examines how housing locations had been changed since the relocation implementation in damaged districts due to the 1933 Tsunami. To choose research objective villages in the affected areas by the 1933 Tsunami, we laid down the following conditions.

4.1.1. Districts of which we can assemble the information of the recovery plans after the tsunami
The research aims at understanding of the housing location transition from 1930s, when the safer resettlement were prepared for the victims after the 1933 Sanriku Tsunami, to the present day. Thus, it is necessary to exactly know the recovery plans from existing sources.

4.1.2. Districts that we can understand the exact location of the post-tsunami resettlement based on the recovery plans
In order to examine the transition of housing location, it is indispensable to follow spatial data of the sites. Thus, whether the exact relocation site can be found in Government's report (Prewar Home Ministry, 1934) is an important factor to choose the objective areas.

4.1.3. Districts that were caused immense damage by the tsunamis in 1896 and 1933
The research focuses on tsunami-prone coastal areas that had been damaged by both the tsunamis in 1896 and 1933, so the slight damaged areas were eliminated from the objective areas.

As a result of careful selection, the seven districts were chosen as shown in Figure 1: (1) Taro, (2) Ryoishi, (3) Katagishi, (4) Koshirahama, (5) Hongo, (6) Kerobe, and (7) Urahama.

4.2. Transition of Housing Location Based on Aerial Photographs after the 1933 Showa Tsunami

According to the above strategy of post-tsunami recovery, the residents started new lives, but the situation of housing location had been changed by the 2011 Great East Japan Earthquake and Tsunami. Here how the location had been changed for about seventy years is looked over using aerial photographs provided by GSI (2007).

The available photographs for the seven areas are as of 1948, 1966, 1968, 1977, 1981, 1991, 1997, and 2000. In addition to those photos, aerial photographs on Google Maps are used to understand the latest situation. Besides, photographs in the report on recovery plan (Prewar Home Ministry, 1934) are referred. Consequently we could arrange those decadal spatial data and understand the chronological change of housing location in the areas.

At first, the change of the number of households from 1949 to 2010 (Iwate Prefecture, 2010) is examined. The population of every village increases after the World War II until the end of 60s with Japanese rapid economic growth, but differences are seen after 70s. The number of households in Taro dramatically decreases around 1970, for Taro Mine, a chief industry in those days, was closed in 1971. However it gradually increases after that. The population of Okirai constantly increases for seventy years. On the other hand, it gradually decreases after 70s in Unosumai and Touni.

Secondly the change of housing location in the seven areas is illustrated based on the photos. Figure 4.1 is an example, for Ryoishi as of 1948, 1977, and 2010. It is recognized that many buildings had been constructed not only in the lots for resettlement, but also in the coastal areas as of 1948. As of 1977, about thirty years after 1948, more buildings had been built in the lower area though a seawall had been completed to reduce the power of tsunamis. By 2010, other buildings have appeared in the east. The tendency that the number of houses increases in dangerous coastal areas according to the passing of time can be seen in Figure 4.2 for Hongo.

Table 4.1 is a qualitative description based on the aero photo observation. It also shows the number of buildings in the higher lands and the coastal lands as of 2010. It is summarized for all objective areas as follows: (1) Houses increase out side of the recovery-planned districts for safety Tsunami after 1960s, (2) there is a tendency that houses increase around the seawalls after those construction, and (3) houses gradually increase along the coast line after 1980s.

To understand the transition of housing location quantitatively, we investigated the number of housings in the coastal areas that are supposed to be inundated by future tsunamis. The number of buildings and the building ratio in the inundated area to all are shown as of 1948, 1977, and 2010 in Table 4.2. In Taro, they determined to keep stay in the inundated area with the safe seawalls, so nearly half number of buildings exists in the area as of 1948. However, the houses in all areas gradually increased toward the coast even though they were forced to move to higher lands in the recovery plan.

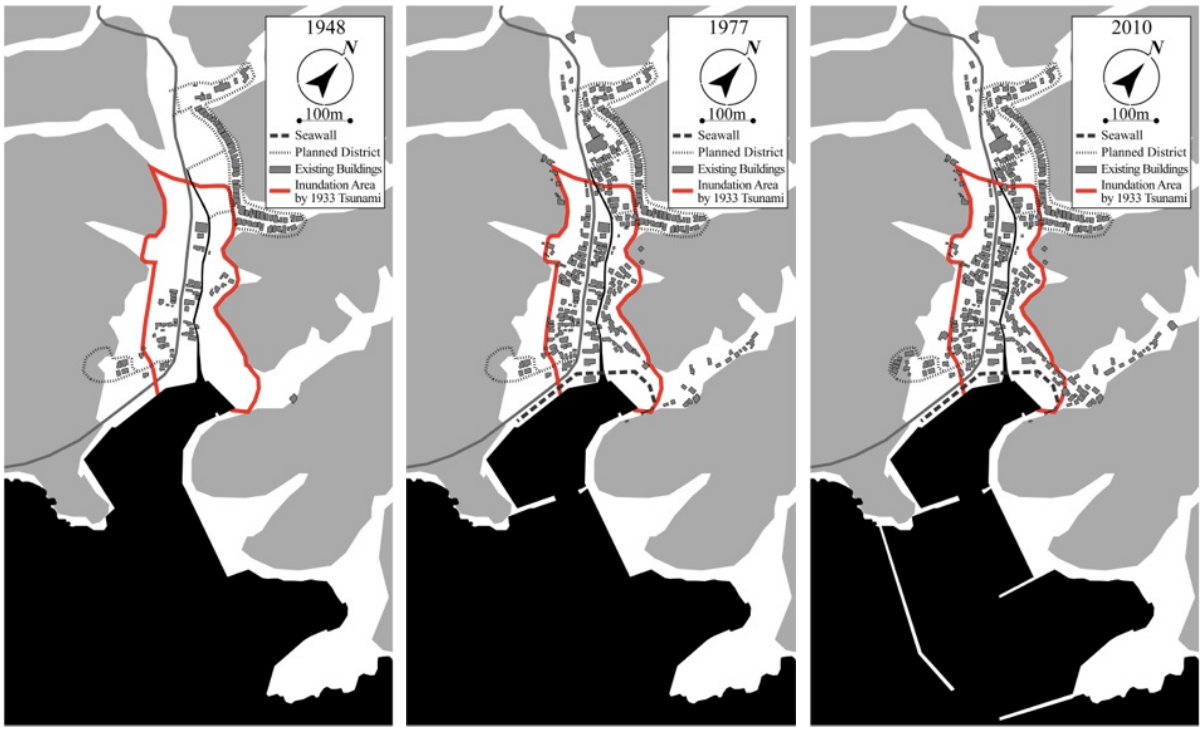

Figure 4.1. Change of Housing Location in Ryoishi, Unosumai Village

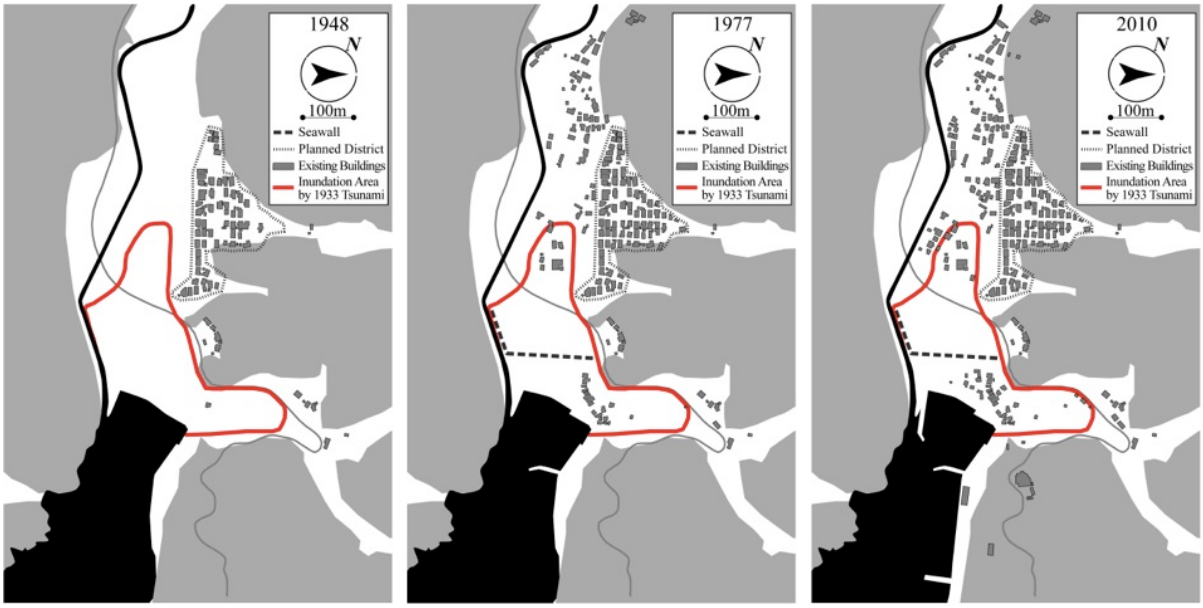

Figure 4.2. Change of housing location in Hongo, Touni Village

Table 4.1. Number of Houses as of 2010 and Construction Process after the 1933 Sanriku Tsuami

	Number of Buildings	1940-	1960-	1970-	1980-	1990-	2000-
Taro	High land: 516 Coalstal land: 1,382	Seawall I is constructed	Seawall II is constructed	Seawall III is constructed			
		Houses are constructed in the recovery-planned district.		Houses are built around the 2nd seawall.		Houses are built around the 2nd and the 3rd seawalls.	
Ryoishi	High land: 96 Coalstal land: 297		Seawall is constructed		Seawall is made higher		
		Houses are constructed in the recovery-planned district, and houses appear in the coastal area.		Houses are built in the inundated areas by the tsunamis and the settlement expands to the east lower area.			
Katagishi	High land: 47 Coalstal land: 287				Seawall is constructed	Seawall is constructed	
		No building except the recovery planned district.		Houses increases in the coastal area as well as higher.	Houses increase in the backside of the seawall.	More houses are built around the seawall.	
Koshirahama	High land: 217 Coalstal land: 217		Seawall is constructed	Seawall is made higher			
		Many houses far away from the coast.		Houses increases in the plain coastal area.		Houses increases in the east side of the seawall.	
Hongo	High land: 156 Coalstal		Seawall is constructed and tsunami				

	land: 170		control forest is planted		
		Houses are constructed in the recovery-planned district.		Houses increases around the seawall and other lower area.	Houses increases inner land of tsunami control forest.
Kerobe	High land: 51 Coalstal land: 85			Prevention facilities are constructed.	
		Houses locate in the recovery-planned district as well as outside.		Settlement expands in the mountain.	Houses slightly increase along the coastline.
Urahama	High land: 697 Coalstal land: 221		Seawall is constructed		
		Houses are constructed in the recovery-planned district.	Houses gradually increase along the coastline.		Houses slightly increase in the east coast

Table 4.2. Change of the Number of Houses and Building Ratio in the Damaged Coastal Areas by the 1933 Sanriku Tsunami

	Taro	Ryoishi	Katagishi	Koshirahama	Hongo	Kerobe	Urahama
1948	869 45.8%	49 12.5%	10 3.0%	30 6.9%	1 0.3%	2 1.5%	28 3.1%
1977	1,079 56.8%	154 39.2%	30 9.0%	87 20.0%	30 9.2%	15 11.0%	39 4.2%
2010	1,209 63.7%	171 43.5%	79 23.7%	102 23.5%	54 16.6%	25 18.4%	66 7.2%

5. RESIDENTS' TSUNAMI RISK RECOGNITION

The tendency of increasing of residents in the coastal areas or the lower lands depends on residents' individual conditions. In order to clarify the reasons, the authors conducted interview questionnaire survey with residents in the seven objective districts in December 2010 and January 2011. The number of examinee is 100 households: twenty-eight in the higher lands, and seventy-two in the coastal or the lower lands. The questions consist of (1) the housing location process, (2) basic reasons of living on or moving to the site, and (3) tsunami risk recognition.

Figure 5.1 illustrates the chronological change of housing location of the 100 households. As a whole, sixty-nine households inherited the lands from their parents, twenty-two came from outside of the town, and nine had moved from the higher lands as of January 2010. Thirty-three households who had lived in the higher lands until 1940 relocated to the lower lands by 2000.

The reasons of living in the coastal areas are shown in Figure 5.2. The dominant reason of the people from outside is "No reason," and it includes economic and occupational situation. The resident answering "Necessarily" told "there is a land slide risk in the mountainous area, and there is a tsunami risk in the coastal area. We cannot live in the area without facing risks." As for the residents from high lands with white color in Figure 5.1, they were born in the higher lands after post-tsunami relocation in their parents' generation, but they moved to the inherited coastal areas to seek more

convenient or confortable lives when they got married.

Figure 5.3 shows the tsunami risk recognition of the people from outside at the time they chose the coastal areas. Nineteen out of twenty-seven (70.4%) recognized the risk in the coastal areas. Eleven people among them (57.9%) considered existence of seawalls. Some of them answered that they would not have moved to the coastal areas if the seawalls had not been constructed. Two people who had a thought of seawalls did not have tsunami risk recognition because they thought that the seawalls could mitigate tsunami disaster.

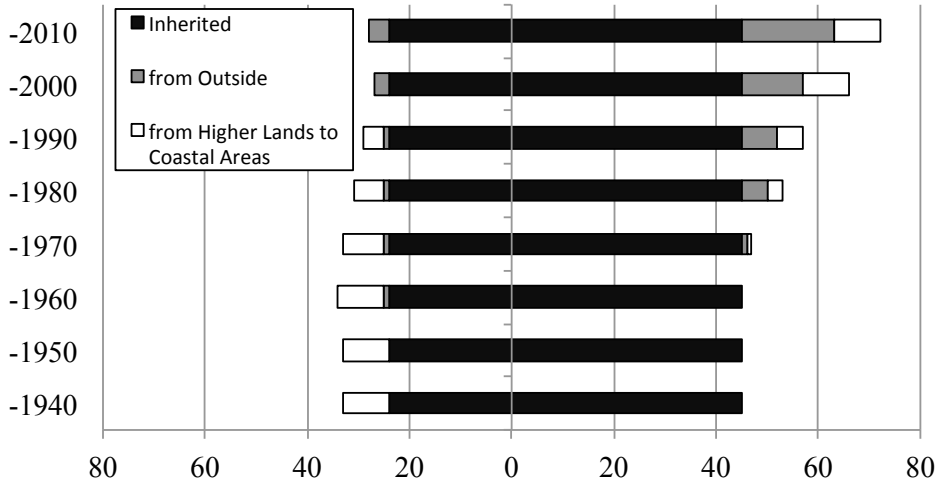

Figure 5.1. Change of Moving Conditions of Household in Higher Lands and Coastal Areas

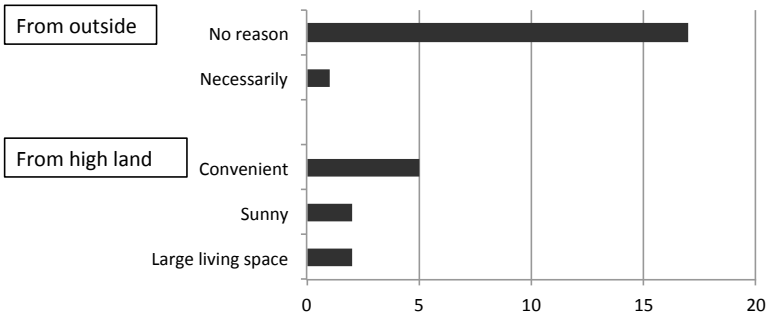

Figure 5.2. Reasons of living in the coastal areas

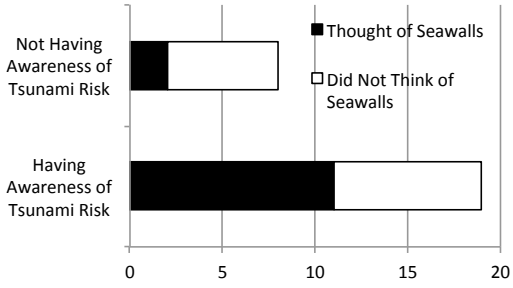

Figure 5.3. Tsunami risk recognition at the time the residents chose the coastal areas

6. CONCLUSION

In order to make useful suggestions as to future tsunami urban recovery policies, the authors examined the transition of housing location in the damaged areas due to the Sanriku Tsunamis in Iwate Prefecture, Japan. Then, comparing the sequential aero photos after the 1933 Tsunami, it presents that the number of housing had increased in the coastal areas in the objective seven districts: Taro, Ryoishi, Katagishi, Kojirahama, Hongo, Kerobe, and Urahama. It also clarifies the reasons based on the field survey and interviews to residents. The result will be helpful to consider the post-tsunami recovery plan in the damaged areas due to the 2011 Great East Japan Earthquake and Tsunami.

AKCNOWLEDGEMENT

This research was supported by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research under Grant No. 23404019, Scientific Research (B) "Examination of Urban Recovery Plans after the 2004 Indian Ocean Tsunami and Urban Risk Evaluation of Tsunami in Asia Influenced by Global Warming." The authors also acknowledge the support from the residents in Iwate Prefecture for the interviews with our sincere condolences.

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