# MORPHOLOGICAL CHANGE AFTER THE TSUNAMI AROUND NATORI RIVER MOUTH

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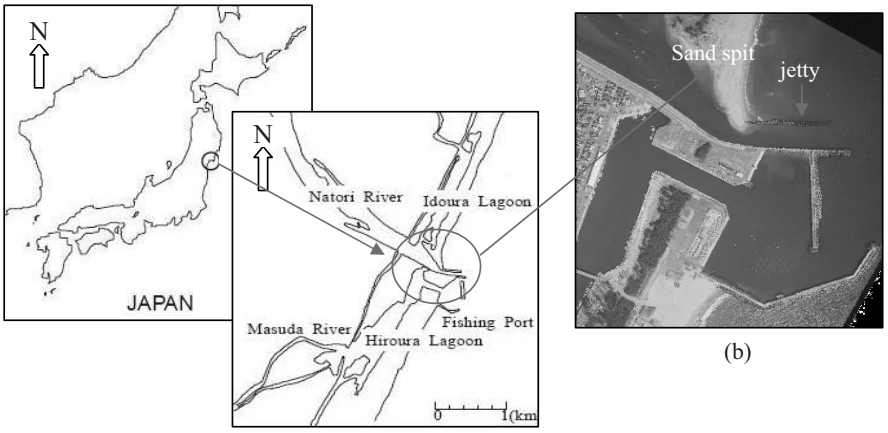
## ABSTRACT
Tsunami is a serious form of natural disaster that affects the coastal ecosystems. Natori River is one of affected area. Before tsunami, the Natori River was protected by sand spit which act as natural barrier. After tsunami, the sand spit was declining to the landward area and change the width of the river mouth. In the present study, morphological change around the mouth of Natori River is investigated using aerial photograph. The result shows that the sand spit is declining around 125 m to the landward and migrate the position of river mouth 180 m from the previous position.

## 1. INTRODUCTION
An estuary is the transition between two distinct water bodies; a river and sea (Savenije, 2005). Although influenced by the tides, they are protected from the full force of ocean waves, winds, and storms by such land forms as barrier islands or peninsulas (EPA, 2011).

Natori River played important role in fishery industry. Yuriage Fishing Port is located near Natori River mouth and has high activity with only 7,000 populations (Yalciner et.al. 2011). During Pacific Earthquake 2011, Natori River was reported as the one of areas which were most severely badly hit. Previous studies about impact of tsunami in estuaries found that generally the occurrence damages were morphology change (Pari et.al. 2008; Kench et.al. 2008) and higher salinity in ground and surface water (Reddy et.al. 2005). In this study, morphological change around the mouth of Natori River after the tsunami was investigated with emphasis on the sand spit by several aerial photographs, and quantified the result.

## 2. STUDY AREA
Natori River estuary is situated in the East Coast of Japan and directly faced Pacific Ocean (Figure. 1(a)). The estuary is protected by the sand spit. One jetty was applied on right side of sand spit (Figure. 1(b)), and formed an entrance channel to the estuary.




(a)　(b)

**Figure 1. Study area; (a) Location of Natori River Estuary, (b) Lay out of river mouth**

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3.1. Geo-referencing

Geo-referencing is the process of aligning spatial data (points, lines or polygons) with an image file such as a map, aerial photograph, or satellite image. The process of geo-referencing defines the location of an image and assigns it real-world coordinates so that it may be analyzed with geographic data. Six aerial photographs of Natori River mouth in 2011 were collected within the date of 3rd March, 1st June, 6th July, 24th September, 29th October and 26th November. The aerial photograph which taken in 9 May, 2009 and had been rectified according to JGD2000/Japan Plane Rectangular CS X system with the total Root Mean Square (RMS) error of the rectification between 3 and 4 m is used as reference map. Using an ArcMap tool, the six aerial photographs were rectified and aligned with the reference map.

3.2. Identifying, Digitizing and Quantifying

After all of aerial photograph were rectified, we identified the major change around the river mouth in each photograph. In this case, the sand spit in river mouth showed significant change in each aerial photograph so the morphological change study were focused on it.

In order to quantify the result, digitizing process was required. We separate two types of shape line. First was permanent shape line; consisted of the line of port embankment, revetment structure and jetty. Second was shape line of sand bar and sand spit around of river mouth and could be change in each aerial photograph. After digitizing process finished, two basic lines were determined as reference line in measuring the distance between reference line to the port embankment and sand spit. Several line as we called it transect was drawn for interval 20 m across the reference line. In ArcMap tools, we could use measuring tools to find out the length of transect and distance from reference line. Figure 2, describing the reference and transect position.

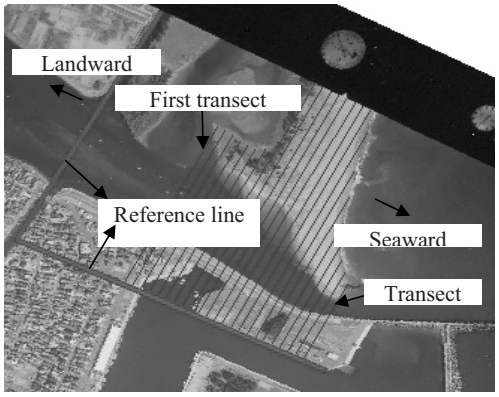


**Figure 2. Definition of reference line and transect**

## 4. RESULT AND DISCUSION

Comparing each of aerial photograph, the sand spit in Natori River mouth shown significant change in each month. Figure 3 showed the morphological change of the sand spit.

**Morphology change three month after tsunami**

The Pacific Tohoku 2011 earthquake in March 11th had washed out the sand spit and moved the tip of river mouth to landward, and leaved the gap between jetty and the sand spit (Figure 3(a)). The width of river mouth became wider comparing to the condition before tsunami. The tip of river mouth was receded around 180 m and width of river mouth was change from 47.77 m to 90.42 m (Figure 4). Around three months after tsunami, the condition of river mouth was not recovered yet, but between 400 m and 500 m from reference line accretion of sand spit was occurred.

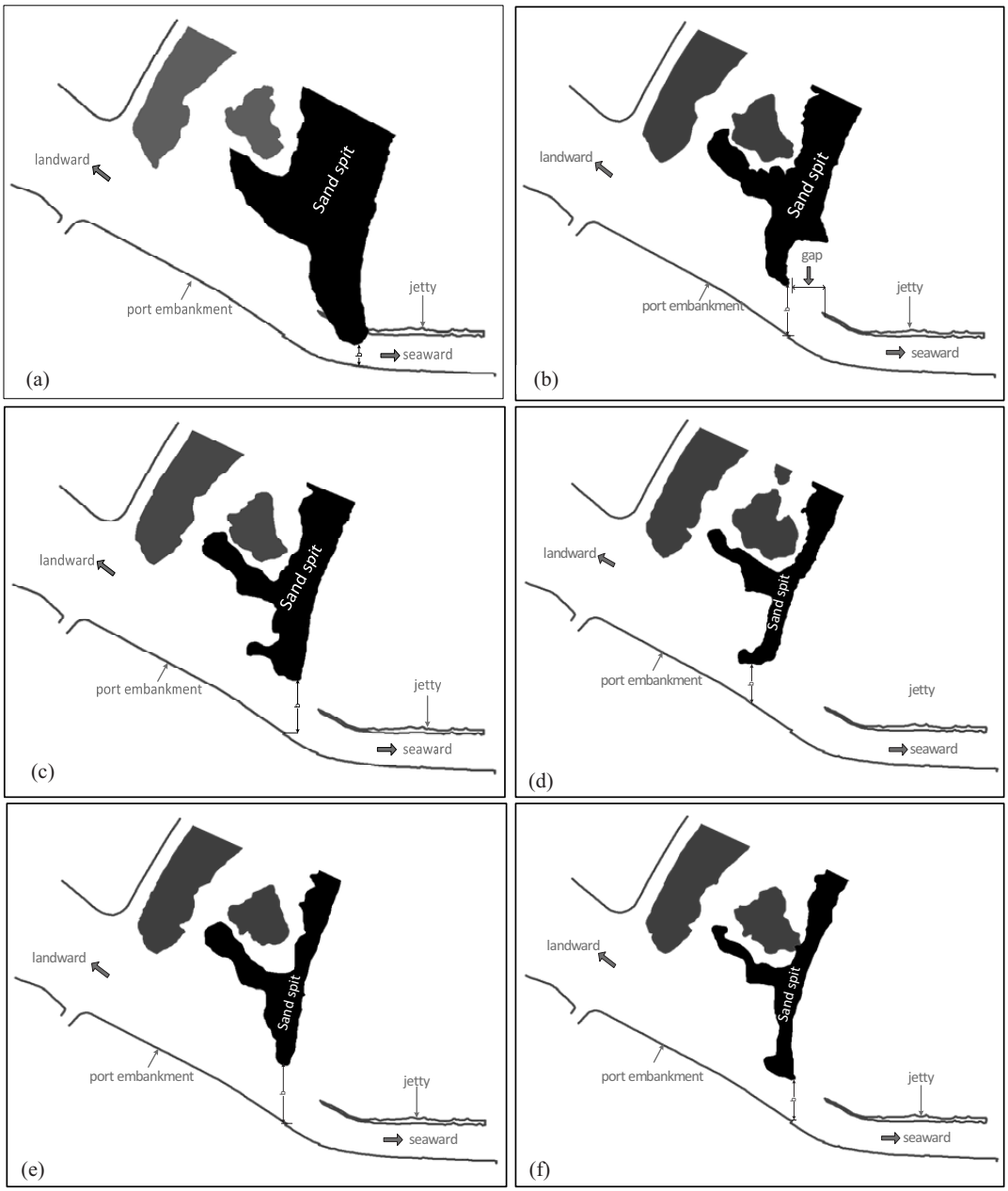


**Figure 3. Morphology of Natori River mouth (a) before tsunami, March 3rd, (b) after tsunami, June 1st, (c) July 6th, (d) September 24th, (e) October 29th, and (f) November 26th, 2011**

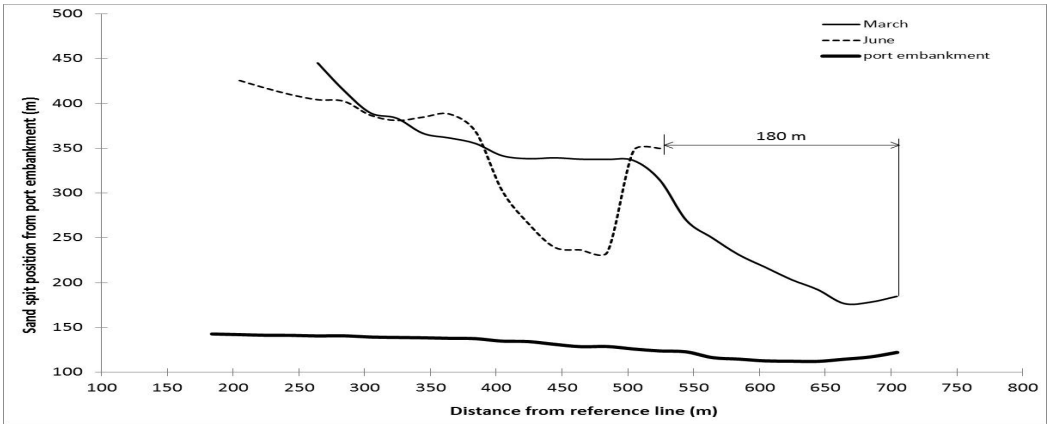


**Figure 4. Tip of river mouth was move 180 m to landward after tsunami event. An accretion of sand spit occurred between 400 m and 500 m from reference line**

Considering the water level during May 30th to June 30th period, the river discharge was tent to be low (figure 5), but it in the beginning of June the water level was higher than in the end of May. The sand spit accretion process might be as a result of sand deposit from the river.

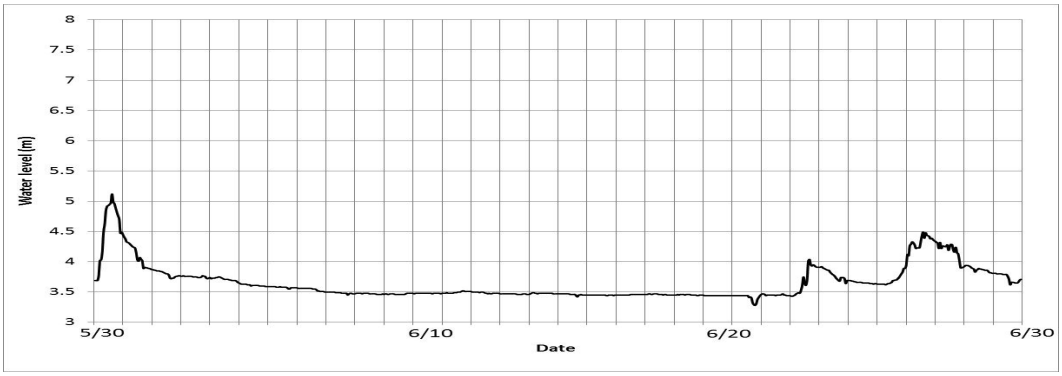


**Figure 5. Water level in Natori River downstream ( May 30th-June 30th, 2011)**

**Morphology change in in June, July and September**

Between June and July, the sand spit was re-formed and narrower the river mouth wide (Figure 6.). Instead of accretion in the tip of sand spit, erosion process also occurred between 400 m to 500 m from reference line and as we can see, the area of accretion and erosion almost in balance. In the end of September 2011, a typhoon hit this area causing high precipitations and river discharge. As a result the sand spit in Natori River mouth was eroded and the opening of the river mouth was widened around 40 m to landward. Considering the river discharge, water level near Natori River mouth during June and July were tend to be low and the morphological change in the river mouth more likely due to wave action.

In September, the typhoon season increasing the water level (21st and 22nd) in the downstream of the river, and we could assume that the erosion of sand spit as a result of high river discharge and wave force from sea.

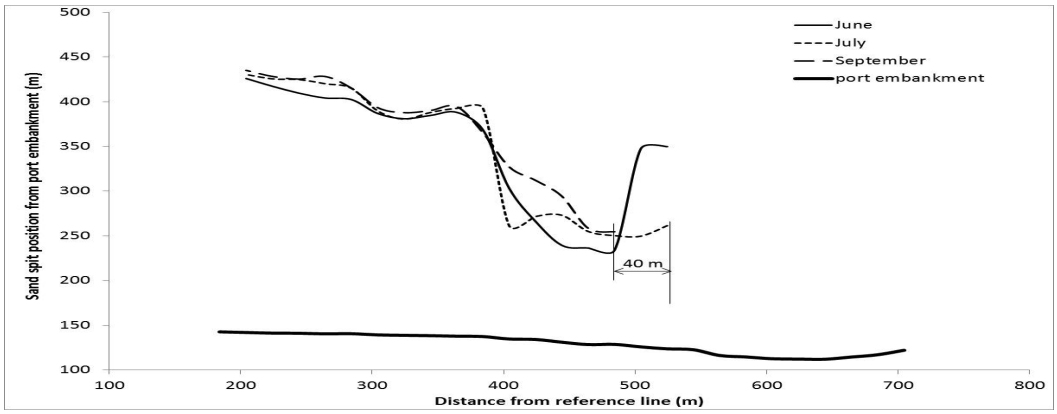


**Figure 6. Comparison of sand spit change in June, July and September 2011**

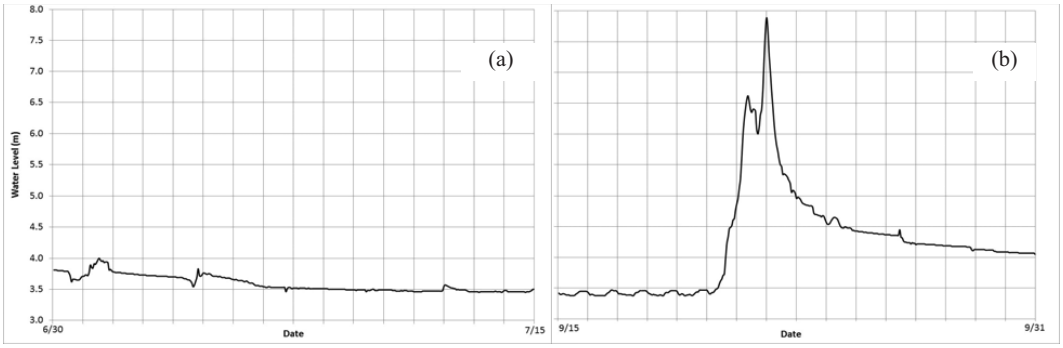


**Figure 7. Water level on (a) June 6th–July 15th, and (b) September 15th– 31st, 2011**

**Morphology change in September, October and November**

Change of the sand spit during September, October and November are shown in Figure 8. One month after typhoon, the sand spit re-formed and move about 20 m seaward. Accretion process also occurred, and the width of river mouth entrance became narrower than in September.

Between October and November, the sand spit was eroded and the tip of sand spit was receded 40 m to land ward. On the other hand, the accretion process occurred between 300 m to 400 m from reference line. Considering the water level, between October 10th to November 25th, 2011 were tend to be low. The erosion process of sand spit likely to have occurred as a result of wave action from sea .Since the discharge from river was relatively small; the accretion process occurred behind the river mouth tip.

## 5. CONCLUSIONS

Tsunami caused morphology change in the mouth of estuary. A sand spit, which used to act as a natural barrier for estuary was eroded and moving the position of river mouth 180 m to the landward area. Between June and July the sand spit re-formed and might be as a result of sedimentation process from river. In September, the sand spit was eroded again due to typhoon season, but during September-October, the sand spit was move seaward and narrowed the opening of river mouth. In October-November period erosion process was continue and move the tip of sand spit to landward side. The wave action could be the most dominant factor in erosion process. Totally the river mouth was move around 280 m to landward after tsunami event, but the width of opening did not show significant difference with before tsunami event. The change position of river mouth will affect the

salinity in estuary and resulting in the change of ecosystem in this area. Considering the important role of Natori River in fishing industry, further study is required to investigate impact of this morphology change to fish habitat and estuary ecosystem. Oceanography data, such as wave and tidal fluctuation should be considered.

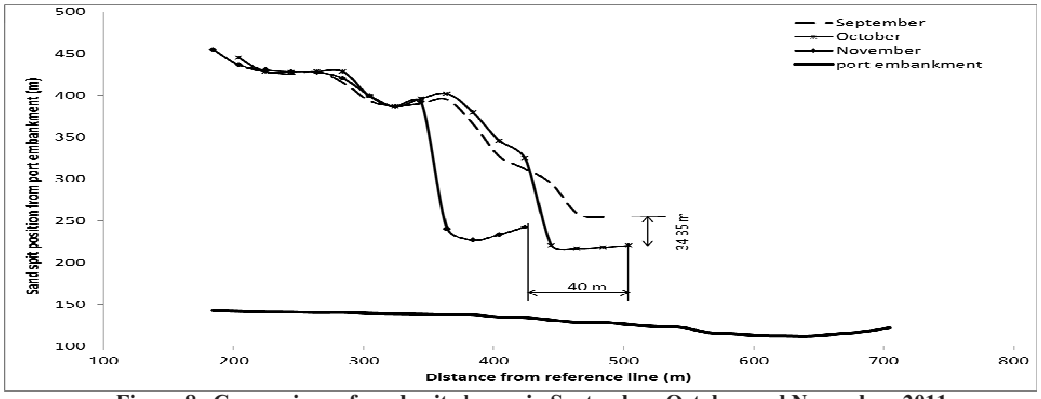


**Figure 8. Comparison of sand spit change in September, October and November, 2011**


**Figure 9. Water level on October 10th to November 25th 2011**

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