Temporal changes in sedimentation patterns within Haboro Harbor

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Abstract

Haboro Harbor is located on the Teshio coast of Hokkaido, Japan, and faces the Sea of Japan. Both sides of Haboro Harbor feature coastal terraces of 20–30 m elevation. The Haboro River flows into the north side of Haboro Harbor. The Haboro Harbor area is commonly buried under sand and silt that has been transported by long-shore drift along the Teshio coast, as well as sediment transported from the Haboro River. In this study, we investigate changes in the sedimentation patterns around Haboro Harbor via cluster analysis of sediments and field-based wave data. We first carried out a cluster analysis of the five predictor variables of coarse sand fraction, fine sand fraction, silt fraction, median diameter of grains, and specific gravity of sediments. The samples were classified into six groups on the basis of the cluster analysis. We then carried out a second cluster analysis using eight predictor variables, adding wave height, water depth, and bottom slope to the five predictor variables listed above. This second cluster analysis revealed five groupings of samples. As a result, we estimated the transportation routes of sediment from the outer to inner Haboro Harbor on the basis of the cluster analysis data, soundings data, and aerial photography. On the basis of the relationship between relative water depth and the Shields number, we classified transported sediments into five groups from the cluster analysis that involved eight predictor variables.
Keywords: sounding, aerial photograph, cluster analysis, sediment, Shields number.

1 Introduction

Since Haboro Harbor was constructed in 1932, use of the harbor has been hampered by the accretion of sediment discharged from the Haboro River and by wintertime wind waves within the harbor. To address these problems, the mouth of the Haboro River was moved to a more northerly site over the period 1975–1982. An increase in the arrivals of large liners and fishing boats led to the extension of protective facilities and the expansion of mooring facilities in the harbor. The Haboro Harbor plays an important role as a fishing base and the base of the line of islands in the northern districts of the Sea of Japan [1].

In this paper, we use aerial photographs of the Haboro River mouth and soundings of Haboro Harbor to analyze temporal changes in sedimentation patterns in the area around Haboro Harbor. We also perform a cluster analysis on the basis of sediment characteristics and wave conditions.

2 Description of Haboro Harbor

Haboro Harbor is located at latitude 44°22′N and longitude 141°42′E on the central Teshio coast, Hokkaido, Japan, as shown in Figure 1. The Haboro Harbor plays an important role in the island line and as a fishing base. Total export trading cargo from the port in 2004 was 81,000 tonnages, made up of ferry cargo (54%), gravel and sand (11%), and other products (22%), while imports of 68,000 tonnages comprised ferry cargo (65%), fishery products (9%), and other products (21%).

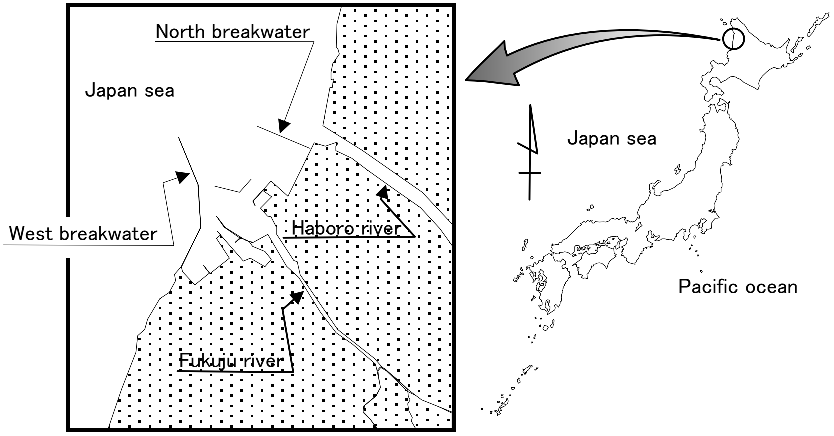

Figure 1: Location of Haboro Harbor.

The Teshio coast is marked by coastal terraces of 10–20 m elevation at Takinoshita and Nakanotaki on either side of Haboro Harbor, as shown in Figure

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2. The Haboro River flows through alluvium north of Haboro Harbor and drains a basin of 269.6 km^2 in area; the length of the river channel is 51.2 km. Haboro Harbor opened as a port in 1935, and the mouth of the Haboro River was moved 150 m from Haboro Harbor during the period 1939–1944 because of shallowing of the harbor caused by remarkably high rates of sediment discharge from the river. The annual volume of sediment discharged from the Haboro River is about 40,000 m^3.

Wave statistics for Haboro Harbor are shown in Figure 3 and Figure 4 [2][3]. The wind direction in this area is dominantly from the W (29%) and NW (19%), as shown in Figure 3. Figure 4 shows the relationship between significant wave heights and wave periods for the wave directions of WSW, W, WNW, NW, and NNW at water depths of 9 m close to the west breakwater of Haboro Harbor.

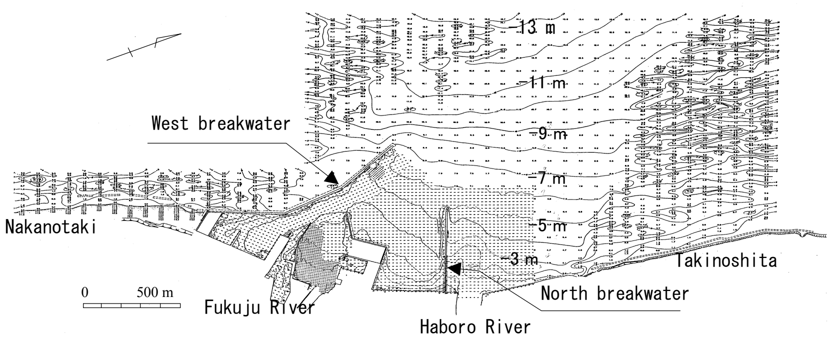


Figure 2: Seafloor topography of the Teshio coast.

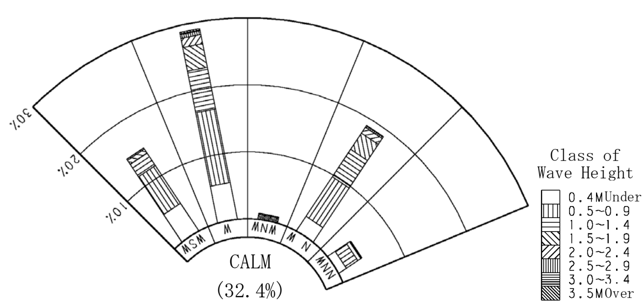


Figure 3: Distribution of wave heights for different wave directions.

3 Changes in the morphology of the Haboro River mouth

We analyzed progressive changes in the morphology of the Haboro River mouth from 23 aerial photographs taken between April 1990 and April 2003, as shown in Figure 5.

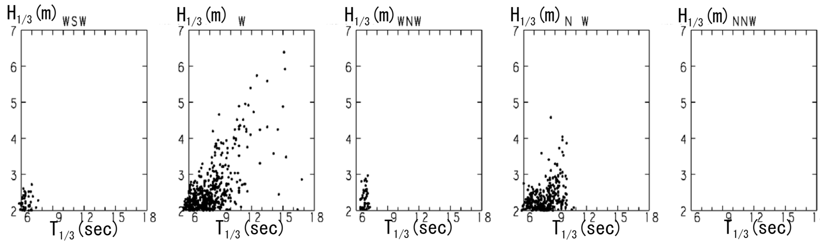


Figure 4: Relationship between significant wave heights and wave period (for wave heights of 2.0 m and above).

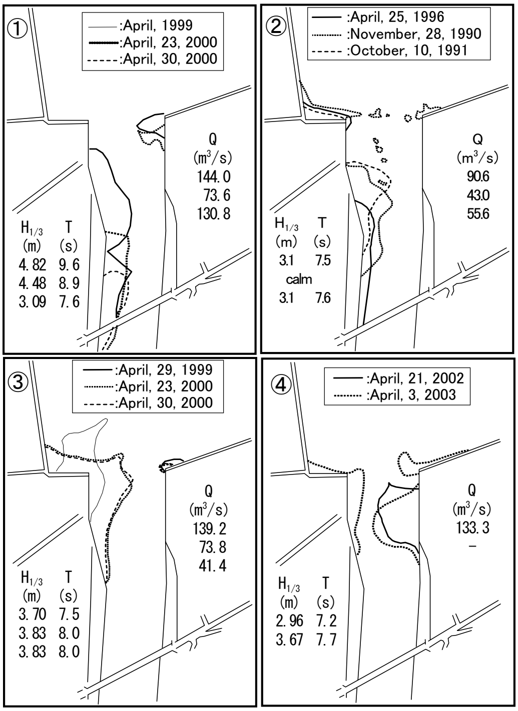


Figure 5: Observed changes in the morphology of the Haboro River mouth, 1990-2003.

Figure 5-① shows the changing topography of the river mouth between April 1990, November 1990, and October 1991. The river-mouth bar of the left bank of the Haboro River progressed upstream over this time, as shown in Figure 5-①. Sand accreted along the concave section of the north breakwater alignment with the extension of the west breakwater from 1996–1997 (Figure 5-②). Figure

5-③ shows changes in the river mouth from April 1999 to April 2000. The accretion of sand along the north breakwater occurred at a remarkable rate, as shown in Figure 5-③. A river-mouth bar developed at the head of the right-hand levee between April 2002 and April 2003, as shown in Figure 5-④. Figure 6 shows changes to Haboro Harbor that accompanied extension of the breakwaters. The west and north breakwaters were extended during the period 1990 to 1996 to prevent the intrusion of sediment into the harbor.

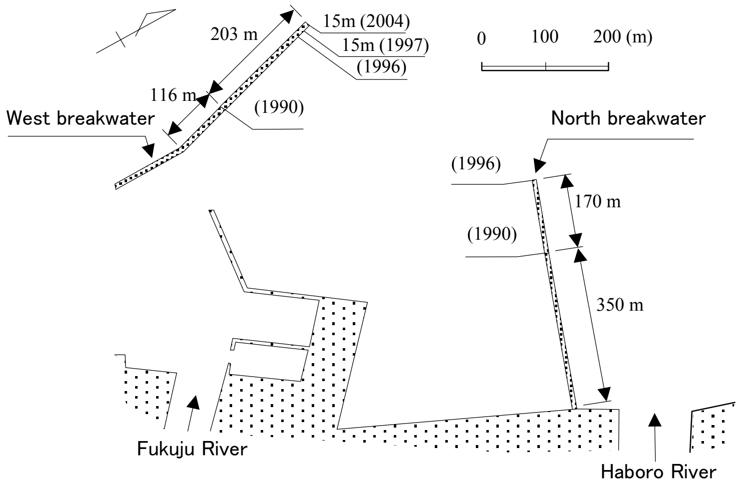


Figure 6: Changes to Haboro Harbor associated with extension of the north and west breakwaters

4 Seafloor topography offshore from the river mouth

We carried out soundings around Haboro Harbor during June 1994, September 1997, and September 1999. Figures 7 and 8 present the results of the soundings.

Figure 7 shows depth profiles along sounding lines 1, 2, 3, and 4 (see Figure 8 for locations of lines.). A plan view of Haboro Harbor and the Teshio coast is shown in Figure 8, along with changes in water depth contours over the period of the sounding observations. Topographical changes along lines 2 and 3 are greater than changes along lines 1 and 4, as shown in Figures 7 and 8. On the basis of these data, we consider that the river-mouth bar formed from sediment discharged from the Haboro River.

5 Movement of littoral drift within Haboro Harbor

We used cluster analysis to investigate the source of littoral drift that caused the shoaling of Haboro Harbor. Cluster analysis encompasses a number of different algorithms and methods for grouping similar objects into respective categories [4].

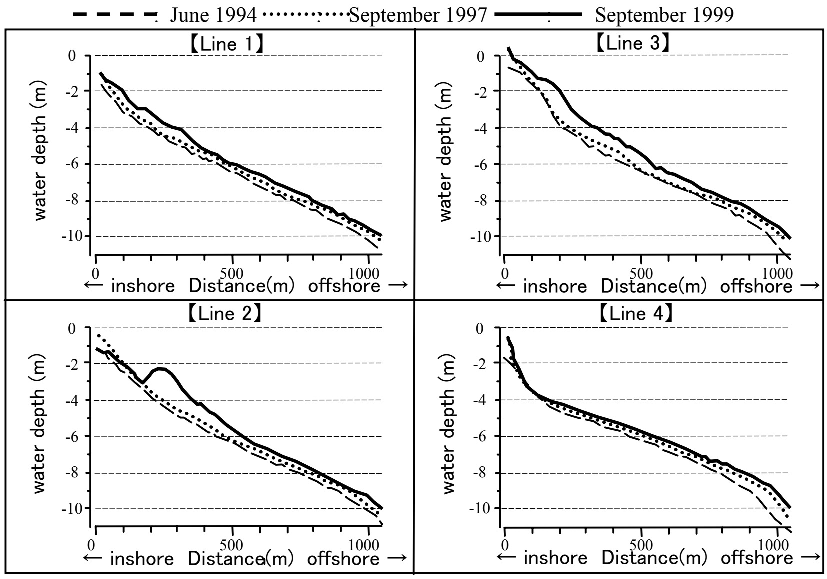


Figure 7: Temporal changes (1994-1999) in seafloor profile along sounding lines 1-4 (see Figure 8 for locations of lines).

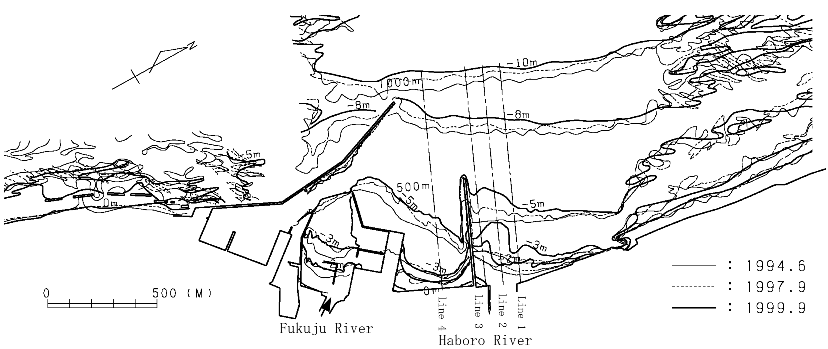


Figure 8: Plan view of temporal changes in water depth along the Teshio coast (1994-1999).

We first carried out a cluster analysis of the five predictor variables of three sediment sizes (coarse sand, fine sand, and silt) in terms of median grain size and specific gravity (Figure 9).

The vertical axis in Figure 9 (a) shows linkage distance, while the horizontal axis shows the six identified groups (G1–G6). The grain size of sediments was very fine and all the sediments had similar characteristics. Therefore, the linkage distance of the hierarchical tree was divided by 0.69 for Groups 5 and 6, and

0.26 for samples in Groups 1–4. Figure 9 (b) shows the six groups identified by cluster analysis and their sample locations. Sediment discharged (G2) from the Haboro River is distributed widely around Haboro Harbor, while offshore sediment (G4) and sediment (G6) along the west breakwater is also found within Haboro Harbor itself (Figure 9 (b)).

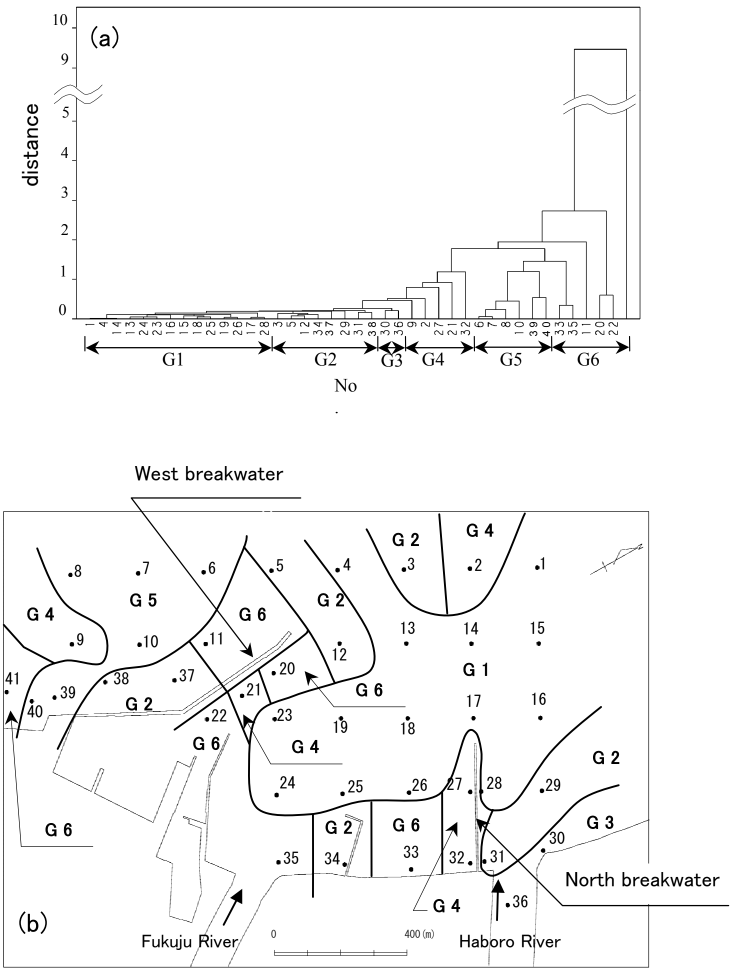
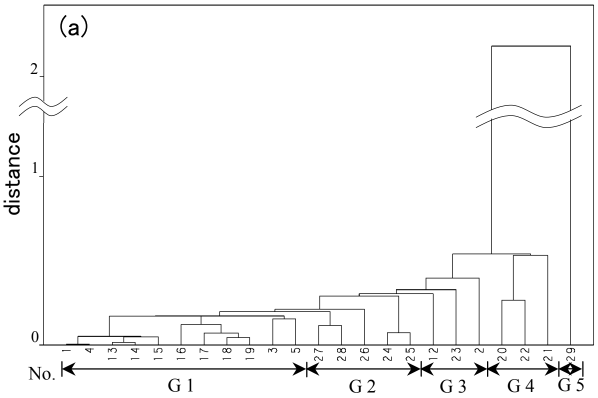


Figure 9: (a) Hierarchical tree of cluster analysis undertaken in this study (five predictor variables). (b) Groupings for cluster analysis (five predictor variables).



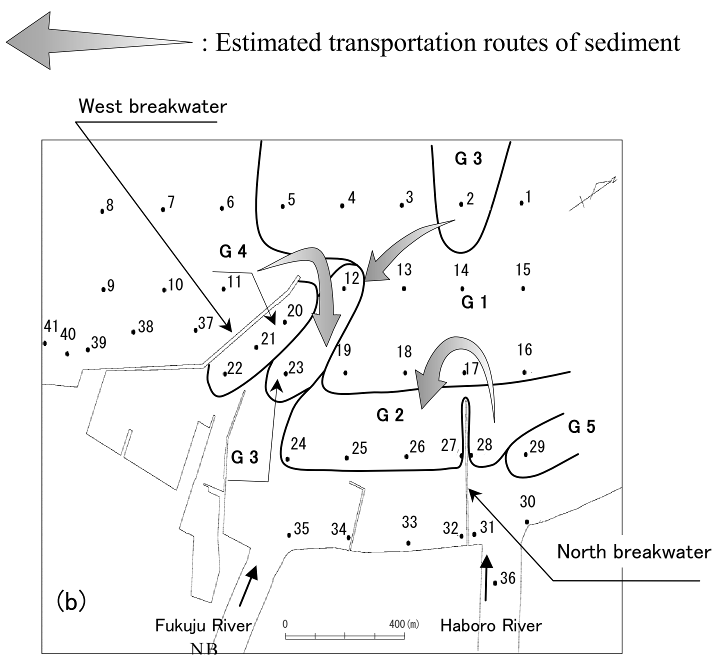


Figure 10: (a) Hierarchical tree of cluster analysis undertaken in this study (eight predictor variables). (b) Groupings for cluster analysis (eight predictor variables).

A second cluster analysis was carried out by adding the three predictor variables of wave height, water depth, and seafloor slope to the five variables considered above. This analysis took into account wave heights calculated at sample points from the maximum significant wave height (2.51 m) and significant wave period (6.8 sec) recorded on January 28 1990, the dominant wave direction (NW), and the seabed slope to the five predictor variables of the first cluster analysis, as shown in Figures 10 (a) and (b). The bed slope was calculated from the difference in elevation between the shoreline and the sample point. A hierarchical tree was constructed with divisions at 0.26 intervals to reveal five groups, G1–G5, as shown in Figure 10 (a). Sediment discharged from the Haboro River (G2) enters Haboro Harbor around the top of the north breakwater, while offshore sediment (G3) invades Haboro Harbor with incident waves and sediment along the west breakwater. (G4) sediment also exists inside the west breakwater, as shown in Figure 10 (b).

Figure 11 shows the relationship between the Shields number and the relative water depth; the Shields number is inversely proportional to relative water depth G1 plots in the traction field, while G2 plots in the fields of sheet flow, suspension, and transition, G3 and G4 plot in the transition field, and G5 plots in the traction field.

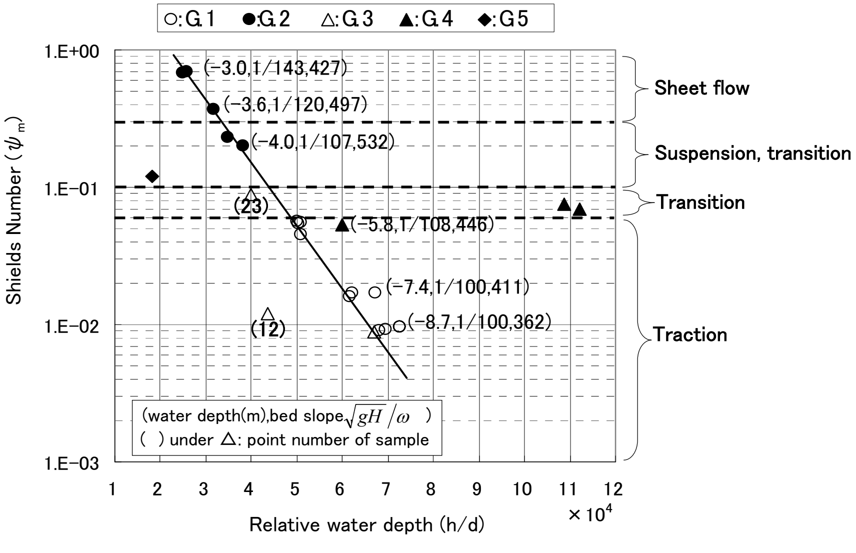


Figure 11: Relationship between the Shields number and relative water depth (g = acceleration due to gravity, H = wave height, ω = sedimentation velocity).

Cluster analysis indicates that G2 and G3 have an effect on sand accretion within the Haboro Harbor, as shown in Figure 10 (b). In addition, G1 traction sediment is the sediment discharged from the Haboro River, while G4 and G5 suspended and transitional sediment occurs in the vicinity of the west breakwater and the mouth of Haboro River.

6 Conclusions

We demonstrated from cluster analysis, soundings data, and aerial photography that sediment discharged from the Haboro River is widely distributed within Haboro Harbor and the area offshore from the mouth of Haboro River. The transportation routes of sand in the area around Haboro Harbor were estimated by cluster analysis of eight predictor valuables. We propose that sediment within Haboro Harbor is accreted by the suspension or transition of sediment that is discharged from the Haboro River.

References

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