AN ATTEMPT TO FIND SMALL ARTIFICIAL OBJECTS IN THE SHALLOW SEA BOTTOM USING A BROADBAND MULTIBEAM ECHOSOUNDER

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Benthic marine litter in coastal waters due to the proliferation of litter in our daily life disturbs trawl fisheries and has the potential to destroy marine ecosystems, although its actual effects are not directly visible. In waters near Japan, knowledge of benthic marine litter outside trawler fishing grounds is limited, because previous studies have mainly taken samples from trawl fishery areas. Thus, to know the spatial distribution of benthic marine litter, we need new techniques that are applicable to a variety of coastal regions, possess sufficient spatial resolution, and require only a few hours to complete a field survey. This preliminary study aims to find small artificial objects on the shallow sea bottom using a broadband multibeam echosounder, and discusses the technological requirements for the detection of benthic marine litter.

Key Words : *marine litter, benthic marine debris, multibeam bathymetric survey, shallow sea*

1. INTRODUCTION

Benthic marine litter around seacoasts disturbs trawl fisheries (Fujieda et al., 2009) and contributes to the destruction of marine ecosystems, although its effects are not obvious since it lies outside the field of our vision. Previous studies reported that the main source of the benthic marine litter is land-based litter, the disposable products found in our daily life (Kanehiro et al., 1995; Shiaku, 2002; Kuriyama et al., 2003; Fujieda, 2007). Fujieda et al. (2010) estimated that the input of benthic marine litter into the Seto Inland Sea was 700 t/y. This value represents 16% of the 4500 t/y total input of marine litter flowing into the Seto Inland Sea.

Bottom trawl nets are commonly used to investigate the distribution of benthic marine litter. Spengler and Costa (2008) reviewed twenty six previous studies on benthic marine litter conducted from 1976 to 2007, and reported that the majority of the studies utilized bottom trawl nets (48.3 %), followed by snorkeling (17.2 %), scuba diving (13.8 %), manta tow (10.3 %), submersibles (6.9 %) and sonar (3.5 %).

Fujieda et al. (2009) pointed out that knowledge of benthic marine litter outside the trawl-fishing grounds around Japan is limited, because samples of the previous studies were mainly taken from these fishing grounds. Ohtomi et al. (2004) have reported on the distribution of benthic marine litter in Kagoshima Bay. Hoshika et al. (2010) conducted a numerical simulation to investigate the behavior of marine litter with both sedimentation and buoyancy properties in the eastern Seto Inland Sea of Japan, and obtained the result that the spatial distribution of litter likely to sediment was much larger than that of buoyant litter due to estuarine circulation.

These previous studies implied that the actual spatial distribution of benthic marine litter will be more widespread than that suggested from the known survey areas. Thus, to know the spatial distribution of benthic marine litter, we need new techniques that are may be applied to a variety of costal regions, offer sufficient spatial resolution, and take a relatively short time (i.e., a few hours) to complete a field survey.

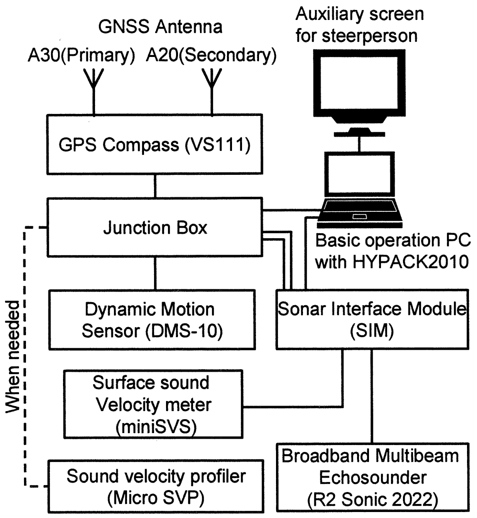

Fig. 1 The R2 Sonic 2022 system and its accessory system owned by Okayama University.

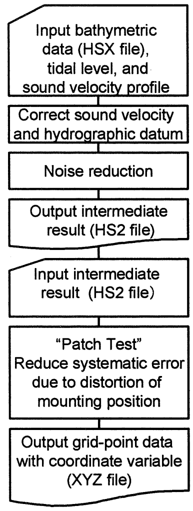

Fig. 2 Work procedure to convert bathymetric data obtained by the R2 Sonic 2022 (HSX file) to grid-point data with coordinate variables (XYZ file).

Underwater sonar equipment, such as the multibeam echosounder and side-scan sonar, can detect objects on the sea bottom not only just beneath the instrument but also 10-100 m on both sides of the probe. With the development of digital technology, the spatial resolution of these tools is rapidly improving. Therefore, these sonar instruments are expected to measure the spatial distribution of small artifacts in a short time. For example, Stevens et al. (2000) detected the possible positions of Tanner crab pots off Kodiak (Alaska) by using side-scan sonar imagery. However, there appear to be additional technological issues to solve before applying the sonar technology to actual benthic marine litter surveys, because the usage rate of sonar technology is presently very small, about 3.5 % according to a recent review (Spengler and Costa, 2008).

This preliminary study aims to find small artificial objects on the shallow sea bottom using a broadband multibeam echosounder, and discusses the technological requirements for detecting benthic marine litter.

2. METHOD

We used a commercial broadband multibeam echosounder, Sonic 2022 (R2 Sonic, LLC), and its accessory system (**Fig.1**) that were introduced by Okayama University with the support of Grand-in-Aid for Scientific Research (A), No.22240084 (Kan et al., 2011a; Kan et al., 2011b; Kamimura et al., in press). The Sonic 2022 has a variable ultrasonic frequency of 200-400 kHz and 60 kHz-signal-bandwidth over its entire frequency range. Its sonar head consisted of a flat array of detectors and a half-round transmitter. It has selectable swath coverage from 10° to 160°, and 256 ultrasonic beams. Its typical ultrasonic beam widths parallel and orthogonal to the direction of travel are within one degree of each other when an ultrasonic frequency of 400 kHz is selected. Although 1.25 cm is defined as the expected value of the vertical resolution for the whole frequency range, the resultant vertical resolution is estimated to be 5-10 cm, because this resolution also depends on the measurement accuracy of the accessory system (Kan et al., 2011a; Kan et al., 2011b). If the beam width is 1°, the theoretical horizontal resolution of the seabed topography is defined as $\pi r/180$ (m), where r (m) is the distance from the sonar head to the sea bed. Thus, just in terms of the beam width, the horizontal resolution of the seabed topography is expected to be less than 10 cm, if r<5 m and the frequency is 400 kHz.

The accessory system of the Sonic 2022 consisted of a GPS compass system (GPS Compass VS111, antenna A20 and A30, Hemisphere Inc.), a dynamic motion sensor (DMS-10, Teledyne TSS Ltd.), a sea-surface sound velocity sensor (miniSVS, Valeport Limited), a sound velocity profiler (MicroSVP, AML Oceanographic Ltd.), a sonar interface module (SIM), a junction box, a basic operation PC with hydrographic survey software

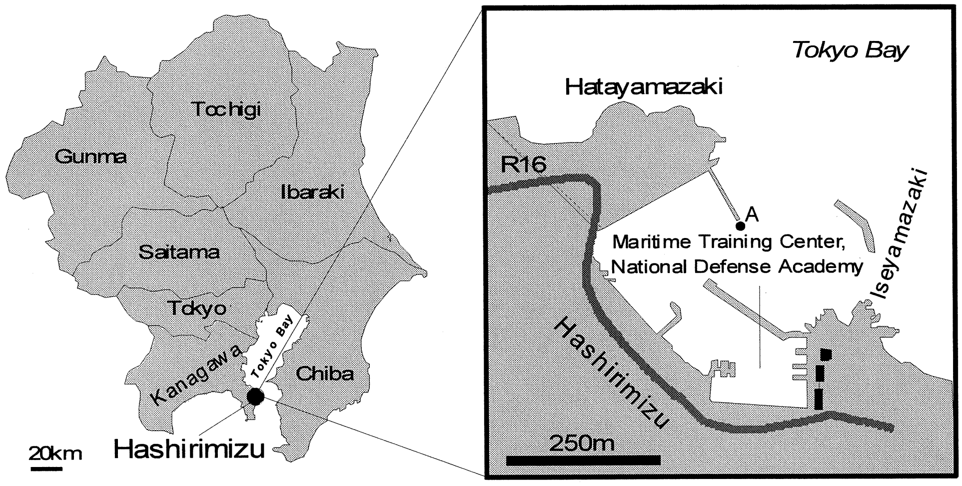

Fig. 3 Location of Maritime Training Center, National Defense Academy.

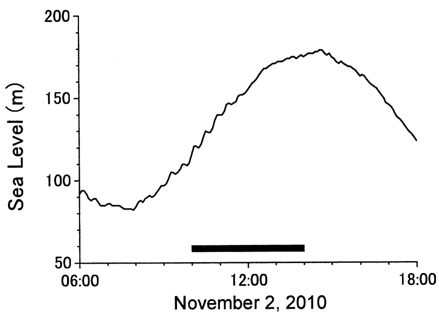

Fig. 4 Real-time tidal level recorded at Yokosuka (Japan Coast Guard, 2010). Tidal datum is 110 cm below the mean sea level. Horizontal black bar indicates the observation time.

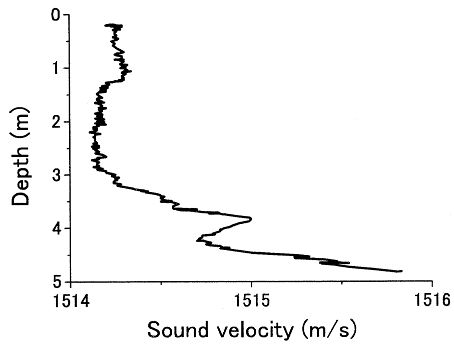

Fig. 5 Sound velocity profile.

(HYPACK2010, HYPACK Inc.) and 3D visualization and analysis software (Fledermaus and iView4D, Interactive Visualization Systems Inc.).

Figure 2 shows a flowchart to produce seabed topography data with coordinate values (XYZ file) from observed primary data (HSX file) using HYPACK2010. First the HSX file, tidal data, and sound velocity profile data are read by HYPACK2010 to correct the tidal datum and the sound velocity. Then a noise reduction process is carried out either manually or by using a digital filter, because the intermediate file (HS2 file) contains noise due to false reflection of the ultrasound, etc. After that, correction of systematic error due to deviation from the correct position of the sensors on the hull is conducted with special data ("patch test" in **Fig**.2). Finally, the bathymetric data are interpolated on an equally-spaced coordinate grid and the result is saved as an XYZ file. The XYZ file is read by Fledermaus to draft the 3D seabed topography. In this study, Google Earth (Google Inc.) was used to superimpose the seabed topography onto maps of the surrounding land use.

The field survey was conducted in the Maritime Training Center, National Defense Academy (**Fig. 3**), from 10:00 to 14:00 on November 2, 2010 (Kamimura et al., in press). Japan Zone 9, a plane rectangular coordinate of Japanese Geodetic Datum2000 (JGD2000), was used during our multibeam bathymetric survey. Bathymetric data necessary for the patch test was obtained on the slope near the breakwater at site "A" shown in **Fig. 3.**

The real-time tidal level at Yokosuka (Japan Coast Guard, 2010) was used to correct the hydrographic datum (**Fig. 4**). A vertical profile of sound speed to correct for speed variations at arbitrary depths was obtained in the survey area at 14:45 (**Fig. 5**).

3. RESULTS AND DISCUSSION

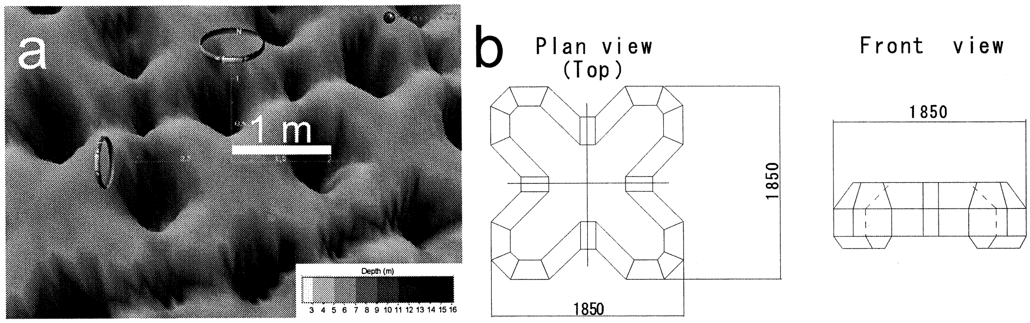

Fig. 6 **a.** Enlarged submarine topography around the breakwater located near site A shown in **Fig. 3**.

b. Three-ton type X block (Fudo Tetra Corporation). Unit: mm.

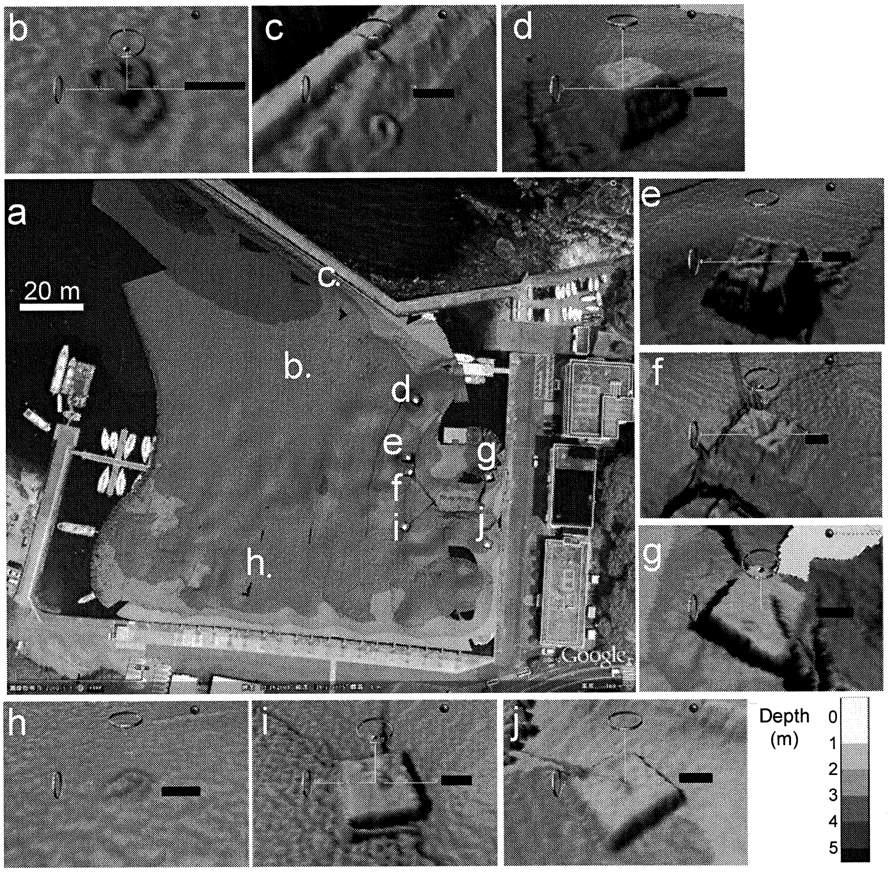

Fig. 7 Possible artificial objects on the seabed in the Maritime Training Center, National Defense Academy. Horizontal black bar indicates a length scale of one meter.

The enlarged seabed topography around the breakwater at site A in **Fig.3** is given in **Fig.6a**, and clearly shows submerged armor blocks. According to the Ports and Harbors Department of Yokosuka City and the Fudo Tetra Corporation, these blocks are 3-ton type X block (Fudo Tetra Corporation). This armor block is 1.850 meters long, 1.850 meters wide and 0.629 meters tall (**Fig. 6b**). These dimensions agree well with the geometry derived by the R2 Sonic 2022. To detect objects like these armor blocks is relatively easy, because the size is large enough and the shape is easy to recognize as an artificial object.

The spatial resolution of the seabed topography in the Maritime Training Center is expected to be less than 10 cm, because the center has a lot of shallow water where the depth is less than 5 m (**Fig.7a**). Thus, by inspection, we determined ten possible artifacts in this area, as shown in **Fig.7b-h**. Six objects seem to be anchor blocks used to connect the floating jetties (**Fig.7d-g, i-j**). Two circular rings around the northern breakwater seem to be tires (**Fig.7c**). In the other two images, the object in **Fig.7h** seems to be a Kenter shackle that is often used to connect anchor chain cable (Ishikawa, 1983). The other object in **Fig.7b** is probably an artifact, because its shape is a combination of three rings.

It can be concluded that a high-resolution multibeam bathymetric survey possesses the potential to recognize artifacts on the seabed of sufficient size and having a distinctive shape. Kan et al. (2011a, 2011b) reported that there was a good correlation between the fine texture on the outer reef slope of Kume Island and the high-resolution multibeam bathymetric data.

4. SUMMARY

We conducted a preliminary survey to find small artifacts on the shallow sea bottom using a broadband multibeam echosounder. The results indicate that this instrument has the potential to immediately recognize small artifacts on the seabed which have distinctive shapes and sufficient size.

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