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Acoustic properties of red tide causing microalgae *Chattonella* sp.: Density and sound speed contrasts and backscattering strengths

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1. Introduction

Harmful algal bloom (HAB), so called '*Red tide*' is a phonomenon which the sea surface becomes discolored red owing to the rapid growth and accumulation of microscopic algae. *Chattonella* sp. is a representative species causing the HABs in the coastal waters of Korea and Japan.

Acoustic technique can be a useful method to the real-time detection of HABs. Kim *et. al.*(2010) measured backscattering strengths using 5-MHz continuous wave (CW) at the costal waters of Korea where the toxic dinoflagellate *Cochlodinium polykrikoides* bloomed, and showed that there was a strong correlation between backscattering strengths and *C. polykrikoides* concentrations.

This paper presents the results of the tank experiment for the acoustic backscatter measurements from single-species cultures of *Chattonella* sp. The results are compared with the fluid sphere scattering model using the density value of *Chattonella* sp., which was estimated by the density gradient centrifugation method.

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2. Measurements

1. *Volume backscattering strengths*

Figure 1 shows the experimental layout of acoustic backscattering measurements from single-species cultures of *Chattonella* sp. 4.25 MHz-CW signals with 0.5 μs pulse length were transmitted into the cultured *chattonells* sp. in the cylinder type water tank (length: 0.47 m, radius: 0.015 m). After completing the acoustic measurements, the water sample in the water tank was pipetted and the cell number was counted using an optical microscopic method. This process was repeated three times.

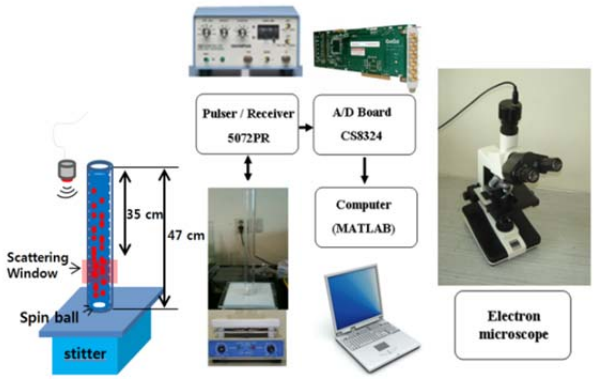

Fig. 1. Experimental layout of volume backscattering measurements.

2. *Density contrast measurements*

Density of *chattonells* sp. was measured by the density gradient centrifugation method using percoll (Sigma Co., Ltd, density 1.13 g/ml) which is a well referenced medium for density gradeint centrifugation of cells. 1.5 M NaCl was added to the undiluted percoll solution to make final solutions of 10 density steps ranged from 1.03 to 1.12 g/ml with a density interval of 0.01 g/ml. The final working solutions were then carefully layered by pipetting in order of density with the most dense at the bottom of the centrifuge tube. The cultured cell was then added. Finally, centrifugation was performed at 400 g for 20 min in fixed angle rotor.

3. Results and discussion

Volume backscattering strengths from the received backscattering signals can be estimated

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using the near-field sonar equation in [1],

$$S_v = RL - SPL + TL - 10log_{10}V \qquad (1)$$

where, S_v is the volume scattering strength (in dB re 1 m^{-1}), RL is the received intensity level (in dB re 1 μPa), and SPL is a combination of source level and one-way transmission loss in near-field which was measured in the transducer calibration experiments (see [1] for details). TL is a transmission loss from the insonified volume V to the transducer. Measured backscattering strengths increases from about –48 to –35 dB with the increment of *chattonells* sp. abundance from about 3.3×10^5 to 5.5×10^6 cells/l (Fig. 2).

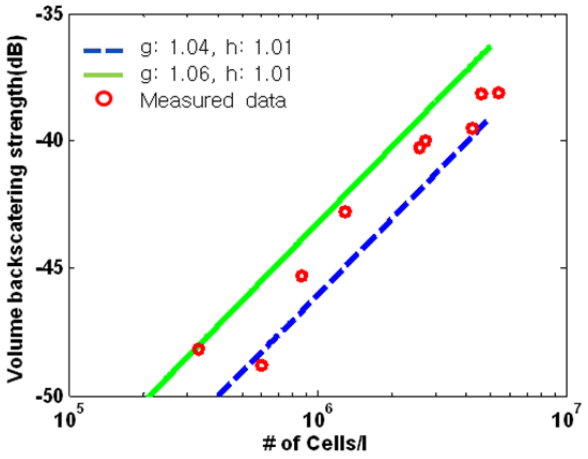

Fig. 2. Measured volume backscattering strengths as a function of *Chattonella* sp. abundance and their comparison to the fluid sphere scattering model predictions.

The measured backscattering strengths were compared to those predicted by a fluid sphere scattering model given by [2]

$$\sigma = k^4a^6\left[\frac{1-gh^2}{3gh^2} + \frac{1-g}{1+2g}\right]^2, \qquad (2)$$

where σ is the backscattering cross section of an individual cell, k is an acoustic wave number, a is the radius of cell. g and h are the density and sound speed contrasts of the cell to the water medium, respectively. Finally, the volume scattering strength is defined as

$$S_v = 10log_{10}(N\sigma), \qquad (3)$$

where N is the number of cells per unit volume. The density contrast range of 1.04 to 1.06 estimated by the density gradient centrifugation method was used to compare to the measured data. The sound speed constrast was, however, not measured at this work. Comparison between the measured scattering strengths and theose predicted by the fluid sphere scattering model using a density constrast range of 1.04–1.06 shows the best fit when the sound speed contrast is 1.01 (see Fig. 2). This value is very consistent with the sound speed contrasts of diatom [3] and zooplanktons [4]. This result implies that an acoustic technique may be an useful tool for monitoring *Chattonella* sp. bloom, though further studies are still necessary.

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