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Fertilizer application to enhance the growth of raft-cultured oysters

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Introduction

Oligotrophication is a serious problem in the Seto Inland Sea, Japan, owing to rapid nutrient reduction measures from the land. A direct effect of nutrient reduction measures has resulted in discoloration of cultured Nori [1], and the measures may affect cultured bivalves.

Hiroshima Bay is the top oyster production area in Japan, with 107,000 tons produced in 2015 [2]. However, production has decreased to 2/3 since the peak production during the 1980s.

According to our analyses, water transparency is relatively high at culture rafts, usually twice as high as that of the surrounding area. This indicates that the filtering activity of hanging oysters is relatively high and implies that phytoplankton abundance may not be sufficient for oyster growth in the rafts.

In this study, we applied fertilizer that we developed [3] to determine if oyster growth could be enhanced by phytoplankton growth caused by nutrient supply.

Materials and methods

Field experiments were conducted in Mitsu Bay, Hiroshima, Japan (Fig. 1). The sea condition of the bay was calm with a current velocity of ca. 0.4–1.0 m s^{-1} [4].

We established three bamboo rafts (10 × 20 m) in the bay, 10 m apart, and at right angles to the longitudinal axis of the average current direction. We used "single-seed" oysters provided by Yanmer Co. Ltd., which were the progeny of a single oyster pair.

Oyster growth and water quality during two growing seasons, October 2014–January 2015 and October 2015–January 2016, were analyzed. The size of the oysters was 24.7 ± 3.0 mm shell length and 1.9 ± 0.6 g weight (n = 124) at the beginning of the first year, and 73.0 ± 12.9 mm shell length and 58.2 ± 18.5 g weight (n = 124) at the beginning of the second year. We placed 20 individuals into a 1 cm mesh size cage in the first year, and suspended them at 1 and 2 m depths.

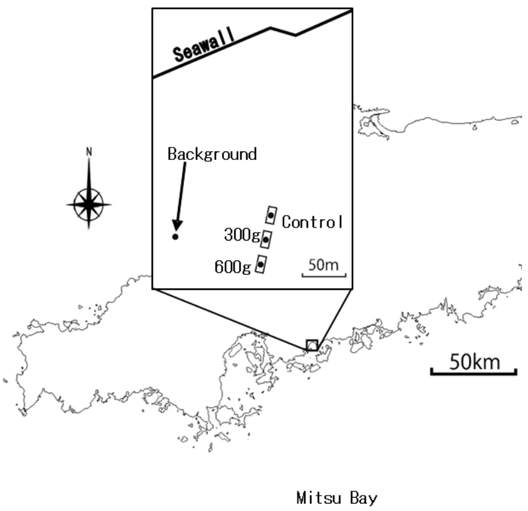

Fig. 1. Location of Mitsu Bay, and arrangement of experimental rafts. Water samples were collected at the center of each raft, and Background, located 100 m upstream of the current. Control, 300, and 600 g indicate raft without fertilizer, raft with 300 g packed fertilizer, and raft with 600 g fertilizer, respectively.

We cultured 1,440 individual oysters in 72 cages at each raft. Therefore, a total of 4,320 individual oysters were cultured at the three rafts. In the second year, we used2.5 cm mesh size cages.

Fertilizer was packed in spunbonded olefin non-woven fabric (Eleves, Unitika Ltd.). For one of the three rafts, a 300 g packed bag was fixed at the bottom of each cage, and for another raft, a 600 g packed bag was fixed in the same way. The last raft was used as a control without fertilizer.

Water samples were collected from a 1.5 m depth using a water sampler (Rigo B type, Rigo Co. Ltd.) at the center of each raft and 100 m offshore from the rafts (Background) before installing oyster cages and several times after installation.

Water samples were filtered through a syringe-type filter with a 0.22 μm pore size (Advantec Disposable Filter Unit, Toyo Roshi Ltd.). The nutrient concentration was determined using an auto-analyzer (QuAAtro TNTP, BL TEC K.K.); dissolved iron (Fe) concentration was determined with an ICP-OES (Optima 7300DV, PerkinElmer Co. Ltd.). Ammonium-N, nitrite-N, and nitrate-N were summed as dissolved inorganic nitrogen (DIN), and phosphate-P was referred to as DIP in this paper. At each sampling site, vertical profiles of temperature, salinity, and chlorophyll fluorescence were measured using a multi-parameter water quality meter (AAQ-117, JFE Advantech Co. Ltd.). During the experimental period, chlorophyll fluorescence at a 1.5 m depth at each raft was monitored with a fluorescence turbidimeter (Infinity CLW, JFE Advantech Co. Ltd.).

Results

No significant differences were observed in the oyster weight and length, and nutrient concentrations between the three rafts in the first year; the results obtained in the second year are described below.

The Fe concentration was ca. 5 times higher in the rafts with 300 g and 600 g fertilizer than that of the control in November 2015, although the DIN and DIP concentrations were not significantly different between each raft, as observed in the first year.

However, the underwater chlorophyll fluorescence monitored during the experimental period was not significantly different at each raft, irrespective of fertilizer application and non-application.

The weight increase rate of individual oysters was 1.4 and 1.5 times higher with the 300 g and 600 g fertilizer rafts, respectively, than that of the control, for the 3-month experimental period (Fig. 2). Particularly, the weight increase of the 600 g fertilizer raft was significantly higher ($p = 0.017$, *t*-test) than the 1.3 times increase of those grown without fertilizer, and was equivalent to a 20% increase than that of the control.

The weight increase rate of oysters in cages was 1.3 and 1.2 with 300 and 600 g fertilizer, respectively, and 1.1 without fertilizer. Oyster growth with 300 g fertilizer was significantly higher than that of oysters grown without fertilizer ($p = 0.017$, *t*-test).

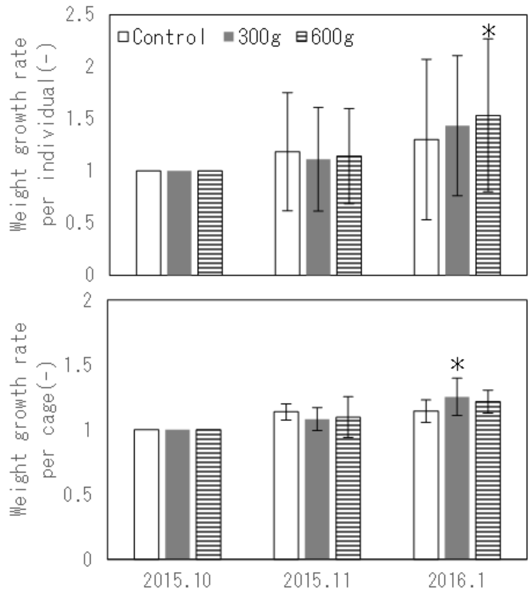

Fig. 2. The weight increase of oysters. Upper: individual basis, lower: cage basis. Bars and lines are average and standard error. Control, 300 g and 600 g indicate the raft without fertilizer, raft with 300 g packed fertilizer, and raft with 600 g fertilizer, respectively. Asterisks indicate statistically significant differences than that of the control raft.

Discussion

Fertilization in the sea is a unique concept, although it is common in agriculture. As mentioned previously, oligotrophication is relatively serious in the Seto Inland Sea, as indicated by Nori leaf discoloration. Since frequent harmful algal blooms (HABs) occurred during the rapid economic growth in 1970s in Japan, there is concern regarding the risks of generating HABs again. Therefore, it will be necessary to calculate how far the eluted nutrients from fertilizers may affect the surrounding area by applying a fluid dynamic model.

In October 2015, the Law Concerning the Special Measures for Conservation of the Environment of the Seto Inland Sea was largely revised, where it was legislated to utilize the Seto Inland Sea as farmland. Therefore, we should not simply reduce the nutrient loads, but maintain the nutrients at a suitable level to culture marine organisms. However, we do not know the most suitable nutrient levels for efficient organism culture. Furthermore, the environmental conditions may be different in each local area depending on the stakeholders. Further scientific analyses are required to propose the most suitable conditions for oyster culture in the Hiroshima area. It is also necessary to develop a numerical model to mimic the food web structure and function in targeted local areas.

Acknowledgements

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