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# Artificial upwelling maintains favorable summer environment for farmed oysters

1 March 2015

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## Pushing colder, nutrient-rich bottom water toward surface layers promotes circulation in the water column



A circular configuration of tubing pumped water up from the lower depths of the bay, resulting in waves on the surface. The aeration center is located at the yellow buoy.

Summer mortality of oysters is a global problem that affects production at commercial farms. Mortalities result from the physiological stress and depletion of energy reserves induced by exposure to stressful environmental conditions. Common seasonal stressors in enclosed bays, where most aquafarms are located, include high water temperatures, eutrophic conditions, fouling organisms and hypoxia, mainly in bottom layers due to thermal stratification of the water column.

Oysters that survive the summer period are often stressed and weak, which usually influences their size, taste of meat and overall quality. Therefore, there is a strong desire for effective mitigative technologies and managements that can overcome summer-related problems during the grow-out phase to guarantee high-quality oysters.

## Artificial upwelling

Artificial aeration upwelling, which consists of pushing colder, nutrient-rich bottom water toward surface layers promotes circulation in the water column and is considered an advantageous method to increase the availability of phytoplankton for filter-feeding bivalves. Nevertheless, only limited research has assessed the possible contributions of the technique to the improvement of temperature, oxygen and bivalve conditions.

To help fill this knowledge gap, the authors designed two aeration systems in cooperation with Ohishi Construction Co. Ltd. and installed them in a summer-stratified, hypoxic bay. The main goal of the study was to check for the possible environmental improvements and related effects on farmed oysters.

## Experimental setup

Collaborative work between research institutes and local farmers of the commercially important Ohmura Bay in Nagasaki, Japan, investigated the effects of aeration on the environment and on farmed Pacific oysters (*Crassostrea gigas*) in the summers of 2011 and 2012.

The aeration was performed from the bottom at two locations: a relatively deep area at 20-meter depth



Artificial upwelling resulted in greater growth and better condition of the oysters, and improved survival, as well.

in the center of the bay, where bottom layer hypoxic water is first formed, and at 5.5-meter depth under an oyster farm whose cages were stocked with juveniles. Air was supplied by tubes connected to compressors at a rate of 1.26 cubic meters per minute for the deeper area and 0.15cubic meters per minute for the farming area.

In both study areas, the sampling stations were located at the aeration center and at increasing distances from it. Water samplings were carried out at 30-day intervals for environmental data, and oysters were sampled at the farming area. Data were compared among stations to check differences induced by the aeration.

## **Environmental improvements**

The effects within 30 meters of the aeration were noted in changes in temperature, oxygen concentration and availability of food.

### ***Decreased water temperature and stratification***

Water temperature was significantly decreased by the upwelling of cold bottom waters. Temperature stratification indices measured by temperature recorders were an average 0.42 degrees-C lower at the aeration point than the furthest station.

## ***Restricted increase in oxygen concentration***

Although restricted only to the beginning of summer and autumn, the oxygen levels were increased in the bottom layer near the aeration (Fig. 1). Although the aeration decreased the oxygen concentration in upper layers above 4-meter depth, during the period of bottom hypoxia, the dissolved-oxygen levels were still above 3 mg/L, which is considered the hypoxic limit. New aeration rates and designs should be tested to guarantee the positive effect of the aeration throughout summer.

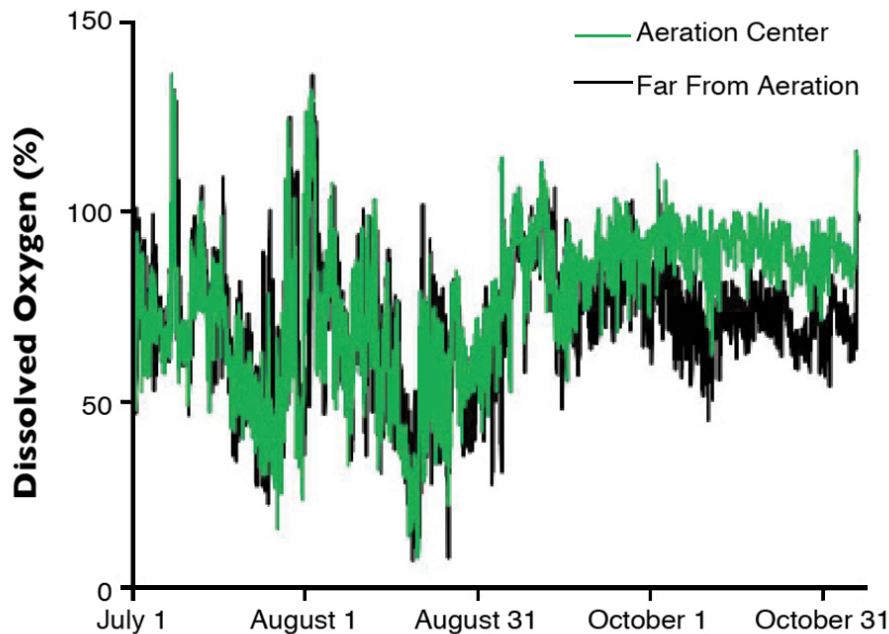


Fig. 1: Differences in dissolved-oxygen concentration at the bottom layer.

## ***Increased food availability and food quality***

The diatom biomass was almost twofold higher at the aeration center than at stations located 60 and 180 meters from it (average values: 162,875 cells/L, 139,433/L and 85,133 cells/L), respectively.

The dominant phytoplankton species changed from dinoflagellates, regarded as poor-quality food for bivalves, to higher-quality food diatoms. Food quality was also assessed by the carbon:nitrogen (C:N) ratios of local suspended particulate organic matter, which indicated progressively higher nutritive rates for the suspended matter as their value decreased. At the aeration point, C:N ratios were lower (Fig. 2).

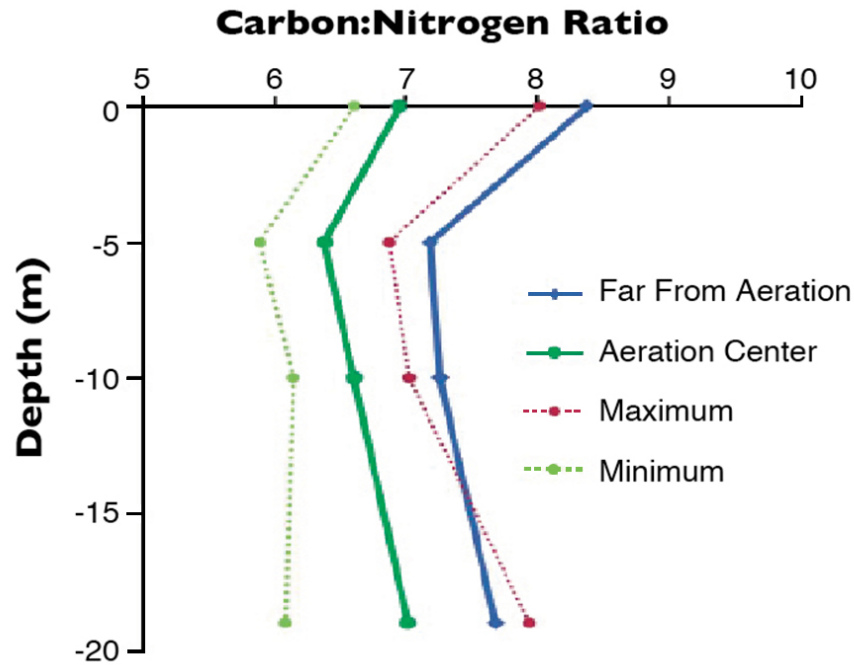


Fig. 2: Mean carbon: nitrogen ratios for suspended particulate organic matter at two locations. Maximum and minimum values at the aeration center are also shown.

## Oyster condition

Oyster overall condition improved, which was proved not only by the shell height growth of almost 9.7 mm/month, but also by higher condition index (C.I.) which is a measure of health and determined by the formula  $C.I. = (\text{dry meat weight} / \text{dry shell weight}) \times 1,000$  (Fig. 3). Total survival was not affected in deep layers, but slightly increased at the surface at the aeration spot (42 percent), when compared to the survival percentages at other locations (30 percent).

Fig. 3: Condition index of oysters in relation to the distance from the aeration point in 2011 and 2012.

## Perspectives

Artificial upwellings were shown to contribute to improvements in farming sites and cultured products during unfavorable periods. However, it is clear the technology should be the subject of future investigations, with assessments of different aeration rates and designs related to each targeted species and possibly under an approach considering global warming.

The costs of aeration were within the usual affordable prices for the fisheries cooperatives in the studied area and resulted in cost-effective positive outcomes. Customized systems, nevertheless, will require strategic planning for each objective in order to provide a basis for decision makers about the benefits of the implementation of such systems for profitable mariculture.

*(Editor's Note: This article was originally published in the March/April 2015 print edition of the Global Aquaculture Advocate.)*

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