Marine Observation Framework Using ICT for Mariculture in Indonesia

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***Abstract*—According to The State of World Fisheries and Aquaculture 2012, a publication of the Food and Agriculture Organization of the United Nations, five Asian nations topped the world ranking of mariculture producers in 2010. In order, they were China, India, Vietnam, Indonesia, and Bangladesh. Asia's maricultural production was 1,799,101 tons in 1970, accounting for 70.1% of the world total. Since then, maricultural production in Asia has continued to grow as a percentage of the world total year by year. In 2010, Asian production reached 53,301,157 tons, about 30 times the 1970 level and 89.0% of global production. World production by maricultural environment shows that about 62.0% comes from freshwater, 7.9% from brackish water, and 30.1% from seawater. Since 2000, the trend is for freshwater production to increase slightly and seawater production to decline slightly. Given this background, promoting mariculture to expand exports of fish and shellfish is a key issue of national development plans in Indonesia, the world's fourth largest maricultural producer. However, maricultural technology is still in the development stage, and production is not stable, plagued as it is with problems like sudden, large-scale die-offs. Maricultural technology can be broadly divided into egg and hatchling production technology and cultivating technology. In Indonesia, egg and hatchling production technology has been under development for high-added-value milkfish and grouper through the "Project for Development of Egg and Hatchling Production Technology for Many Species," begun in 1994. Since 2003, organizations such as a national maricultural research center have been transferring that technology to the private sector. On the other hand, cultivating technology, which concerns raising fish from juvenile to adult stages, is still under development. Here, one issue is the establishment of maricultural technology that enables stable production immune to regime shifts. The authors have begun the observation of the marine environment to establish maricultural technology in Indonesia with the objective of enabling stable production and distribution of safe and reliable fish and shellfish into the future.**

***Keywords*—Mariculture; Marine environments; Observation; ICT, Indonesia**

I. INTRODUCTION

In September 2012, the authors visited a maricultural research center of the Indonesian Ministry of Fisheries and Maritime Affairs in Gondol, Northwest Bali. There, they observed the local egg and hatchling facility and cultivating facility (Fig. 1). One major cultivated type is high-added-value grouper (Fig. 2), eggs and hatchlings of which are produced in a facility on land and cultivated in a facility in the sea. According to the center, production is unstable because of events like sudden large-scale die-offs thought to be caused primarily by cold water masses. Thus, one of the biggest issues faced by the center is the establishment of cultivating technology using observation and measurement of the marine environment.

Fig. 1. Facility of cage culture.

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The authors had developed a so-called "ubiquitous buoy" to support scallop cultivation in Western Hokkaido, Japan, an area that had experienced similar large-scale die-offs as a result of cold water masses. This small and inexpensive buoy was designed to observe water temperatures at multiple depths, costing just one-tenth as much to implement as a conventional ocean observation buoys. By setting up a multi-point, multi-depth water temperature observation network, the authors successfully visualized water temperature distributions below the surface and showed how visualization of the marine environment greatly helps to enhance cultivating technology[1]. Thus, the authors' efforts in Japan would seem to be a strong match for the maricultural needs of Indonesia, and it appears possible that past research findings could be used and developed to visualize the marine environment and establish cultivating technology there.

Fig. 2. Grouper under cage cultivation.

II. MARINE ENVIRONMENT OBSERVATION

Elements of the marine environment that affect fish and shellfish growth and feeding behavior include water temperature, dissolved oxygen, salinity, pH, chlorophyll, and tidal currents. In Gondol, groupers are cultivated in floating cages, which are clustered in water about 15 m deep surrounded by a reef. The area inside the reef is ideal for the floating cages, since it is buffered from the open ocean and therefore the water is stable. As their first initiative, the authors began observations of water temperature (since it is the easiest of the marine environment elements to observe and would seem to correlate with the other elements) and oxygen saturation, which is an indicator of dissolved oxygen, one of the marine environment elements directly impacting die-offs.

A. Observation period

In October 2012, the authors visited Gondol and installed one ubiquitous buoy capable of real-time measurement of oxygen saturation and water temperature at the floating cages inside the reef. Also at this time, they installed record-keeping water temperature gauges called TidbiT[2] at four points inside and outside the reef. In March 2013, the authors visited Gondol again and collected the TidbiT data. A total of 18 TidbiT units had been installed at the four points, and data was successfully collected from six of them. This report concerns the analysis of 158 days (3,792 hours) of observation data from 12:00 AM, October 7, 2012 to 11:00 PM, March 13, 2013 Central Indonesian Time (CIT). Data was observed in one-hour intervals, and ubiquitous buoy observations of oxygen saturation and water temperature, along with TidbiT observations of water temperature, are continuing as of July 2013.

B. Observation points

Fig. 3 shows a map of the cultivating site in Gondol, along with the observation points. The coordinates shown are in Universal Transverse Mercator (UTM) Zone 50. The authors installed a ubiquitous buoy capable of measuring oxygen saturation and water temperature at one floating cage (point X) inside the reef in real time. Of the six TidbiT units from which data was successfully collected, two were located at point A and the other four at point B. Table I lists the coordinates, depth, observation depth (layer), and type of sensors used to make observations at each of these points.

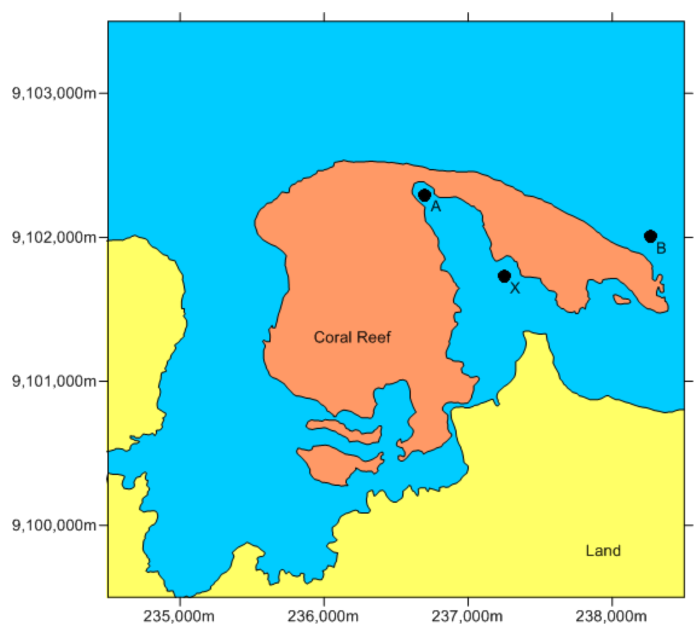

Fig. 3. Map of Gondol with observation points.

TABLE I. DETAILS OF EACH POINT

Point	Position (m)	Depth (m)	Layer (m)	Sensor
A	236701, 9102296	16.7	5, 10	TidbiT
B	238265, 9102003	34.6	5, 10, 15, 25	TidbiT
X	237250, 9101726	15.0	5	ARO-CAD

III. RESULTS AND DISCUSSION

A. *Evaluation of water temperature over time*

Fig. 4 shows the water temperature data over time at points A and B, while Table II shows basic statistics. A comparison of points A and B shows no difference in average and maximum water temperatures, but does indicate a difference of about 1°C in minimum water temperature. Thus, the standard deviation for point B is about 0.1°C greater than at point A. This is believed to be because point B (outside the reef) is more impacted by the open ocean than is the case at point A (inside the reef). Additionally, Fig. 4 shows that fluctuations occur on a short cycle, so the authors used 2,048 hours of data (from 12:00 AM, October 7, 2012 to 7:00 AM, December 31, 2012) to perform a fast Fourier transform and extract the periodic components. Results of the fast Fourier transform are shown in Fig. 5. The vertical axis uses a logarithmic scale. The figure indicates notable diurnal fluctuation at both points A and B. There is also fluctuation on an approximately half-day cycle, which would appear to be because of the tide. At point B outside the reef, notable periodic components of not only 24 hours but also 12 hours and 25 hours are detected the deeper the level, confirming the tendency for the tide's impact on water temperature. At point A inside the reef, on the other hand, the 24-hour periodic component is dominant, so one can say that sunlight has a greater impact on water temperature than the tide does.

B. *Evaluation of water temperature trends*

Since the water temperature data was found to contain 24-hour and 12-hour periodic components, the authors removed these periodic components and converted the data to a 24-hour moving average to find trends in the change of water temperature. Fig. 6 shows the 24-hour moving average over time. At point A inside the reef, the correlation coefficient of water temperature at depths of 5 m and 10 m is 0.995 for the observation period, so no great difference was found in water temperature and trends in the change of water temperature based on depth. At point B outside the reef, however, the change of water temperature tended to differ between shallow and deep water. Table III gives the correlation coefficient for water temperature at depths of 5 m and 25 m, as calculated for each month. The correlation was low in November, December, and February as compared to October, January, and March.

C. *Evaluation of oxygen saturation over time*

The oxygen saturation and water temperature at point X were collected in real time using a mobile phone connection. The ubiquitous buoy developed by the authors works only on the Wideband Code Division Multiple Access (W-CDMA), not the Global System for Mobile Communications (GSM), since it was designed for use in Japan. Using international roaming, a connection was made to an Indonesian carrier, but there was some loss of data because W-CDMA is unstable around the cultivating site in Gondol. The number of data points collected during the observation period was for 2,974 hours of the 3,792 hours of the period, meaning that 21.6% of the data was lost. At first, the lost data was made up by linear interpolation. Fig. 7 shows the oxygen saturation and water temperature over time, after interpolation. Fig. 8, moreover, shows the results of the fast Fourier transform using data for the 2,048 hours from 12:00 AM, October 7, 2012 to 7:00 AM, December 31, 2012. While the 24-hour periodic component was dominant for oxygen saturation, there was also found to be a 25-hour periodic component. For water temperature, however, there was a notable 24-hour periodic component similar to the case of point A inside the reef.

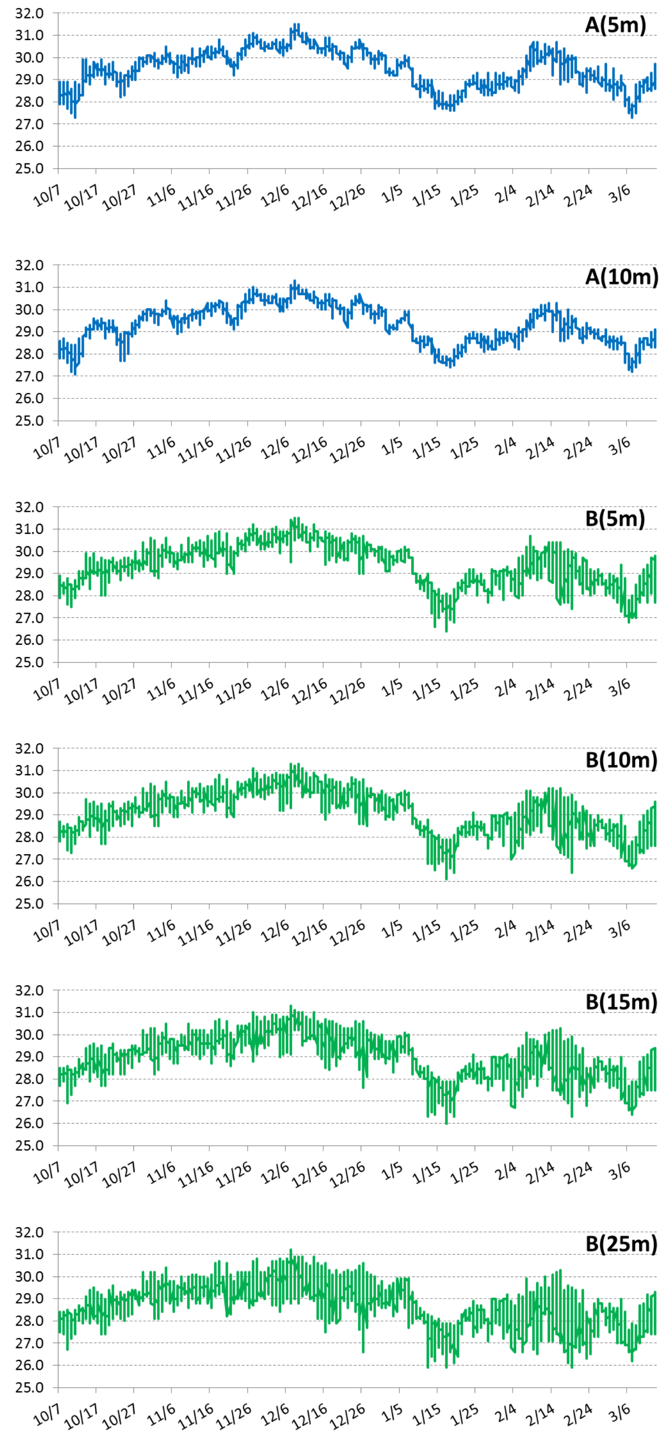

Fig. 4. Water temperature data observed by TidbiT.

TABLE II. BASIC STATISTICS OF WATER TEMPERATURE

Point	A(5m)	A(10m)	B(5m)	B(10m)	B(15m)	B(25m)
Average	29.5	29.2	29.4	29.2	29.0	28.7
Maximum	31.5	31.3	31.5	31.3	31.3	31.2
Minimum	27.3	27.1	26.4	26.1	26.0	25.9
S.D.	0.83	0.86	0.93	0.96	0.96	0.95

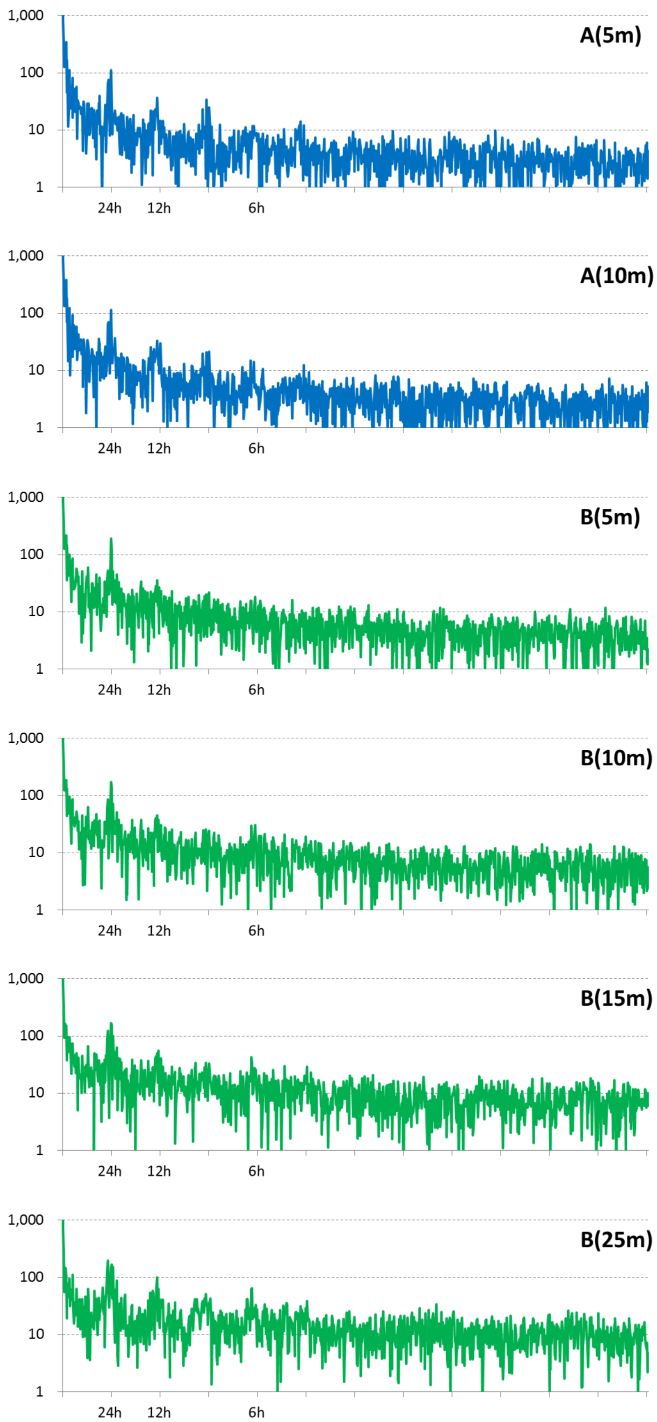

Fig. 5. Power spectrum density of water temperature.

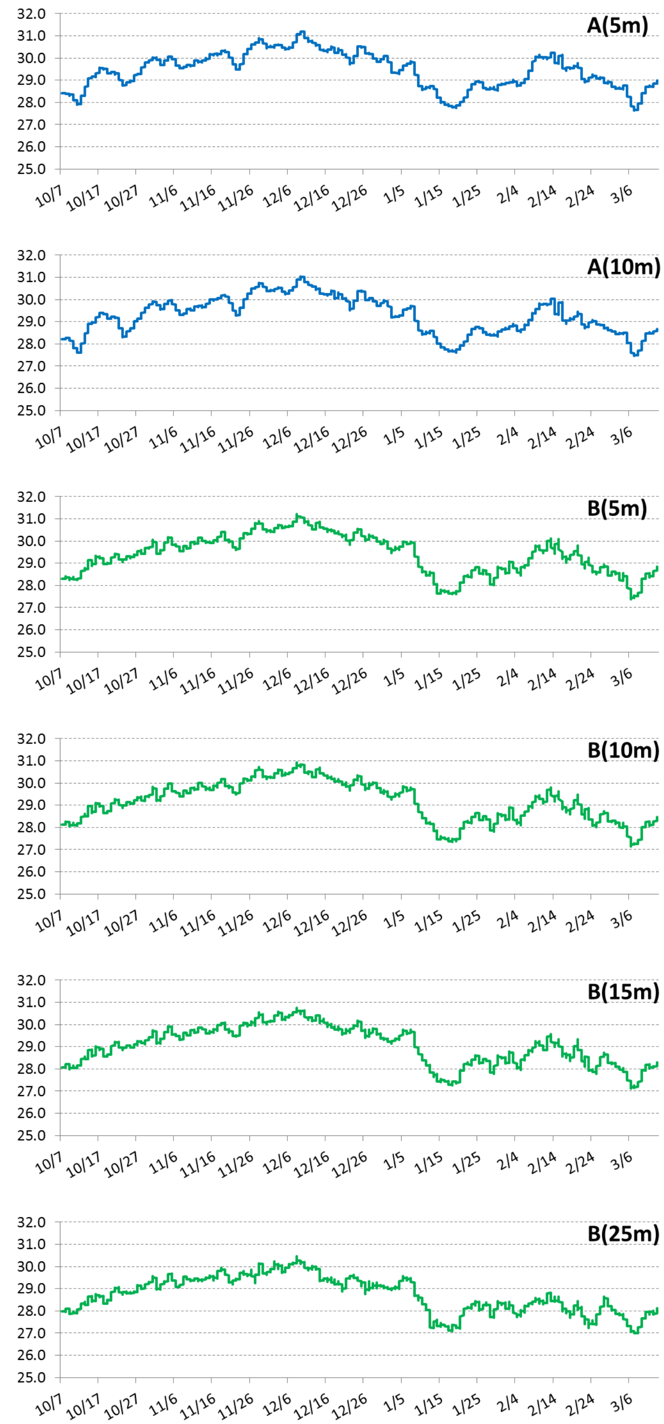

Fig. 6. Moving average of water temperature.

TABLE III. CORRELATION COEFFICIENT FOR WATER TEMPERATURE AT DEPTHS OF 5 M AND 25 M

Month	OCT	NOV	DEC	JAN	FEB	MAR
R	0.978	0.767	0.796	0.967	0.627	0.958

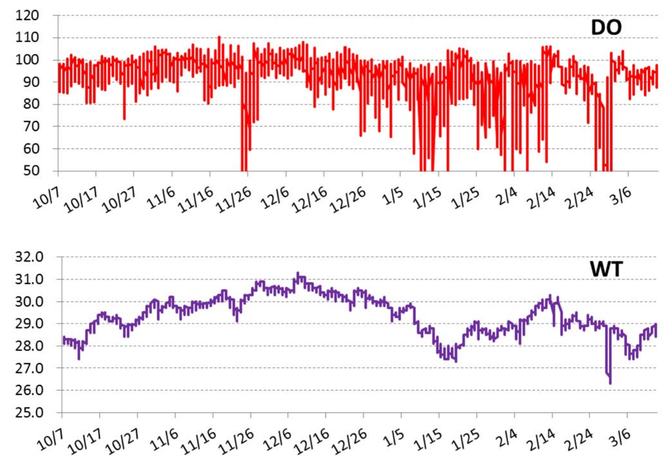

Fig. 7. Oxygen saturation and water temperature data by ubiquitous buoy.

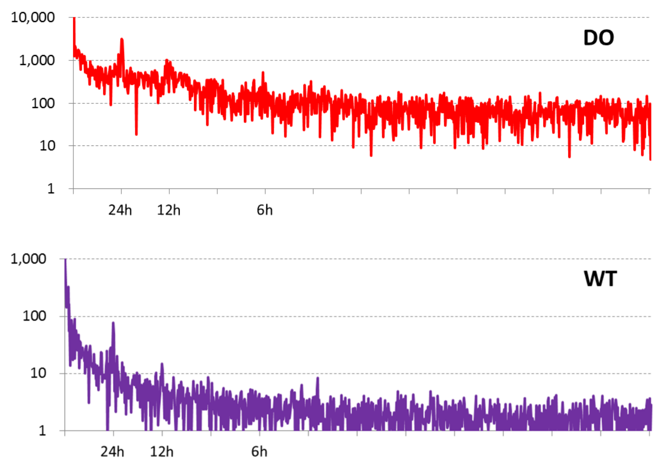

Fig. 8. Power spectrum density of oxygen saturation and water temperature.

D. *Evaluation of oxygen saturation trends*

A 24-hour moving average was also found for oxygen saturation, since the 24-hour periodic component was dominant. Fig. 9 shows the 24-hour moving average of oxygen saturation and water temperature at point X over time. Table IV, meanwhile, shows the correlation coefficient between oxygen saturation and water temperature for each month. The results did not confirm any correlation between oxygen saturation and water temperature. The authors are currently checking the cause of the rapid change in oxygen saturation in late November and again in late February. This check includes a look at any irregularities in observation data. Fig. 10 shows the diurnal fluctuation of oxygen saturation. The graph was made using observation data from December 2012, which does not include the rapid changes. The horizontal axis shows the time of day, while the vertical axis shows differences from observation data at noon for the same day. The time of observation of the minimum oxygen saturation and time of observation of the maximum oxygen saturation coincide with the time of sunrise and sunset, respectively.

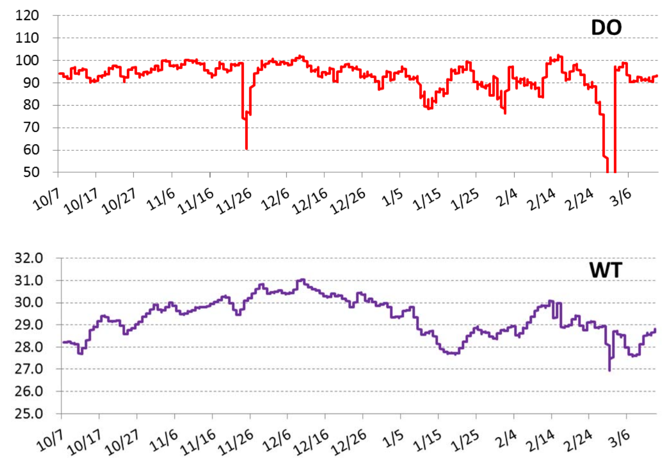

Fig. 9. Moving average of oxygen saturation and water temperature.

TABLE IV. CORRELATION COEFFICIENT BETWEEN OXYGEN SATURATION AND WATER TEMPERATURE

Month	OCT	NOV	DEC	JAN	FEB	MAR
R	0.005	-0.272	0.661	0.173	0.400	0.588

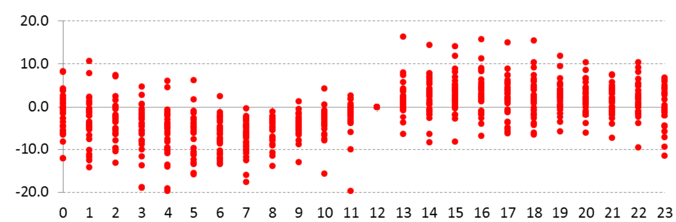

Fig. 10. Diurnal fluctuation of oxygen saturation.

IV. CONCLUSION

This is a progress report on a marine environment observation being conducted by the authors on a cultivating site with the objective of establishing maricultural technology in Indonesia. The marine environment elements observed were water temperature and oxygen saturation. The authors analyzed observation data for the period October to March, which overlaps the rainy season. As a result, there was found to be a notable 24-hour periodic component to changes in water temperature in the sea inside the reef, where the cultivating facility is located. It was also found that the impact of sunlight was more dominant than that of the tide. On the other hand, the water temperature fluctuation in the water outside the reef was found to have notable 12-hour and 25-hour periodic components at 15 m and deeper, where sunlight is not likely to have much impact. Thus it was shown that the tide has a greater impact in deep water than in shallow water. Inside the reef, there was very little difference in water temperature by depth, so water temperature as an indicator would seem to have little relevance to the growth and feeding behavior of fish and shellfish and to mariculture depth.

On the other hand, in the short term, oxygen saturation (an indicator of dissolved oxygen) was found to have a regular cycle of increasing in the daytime and declining at night, but no regularity was found in the long term. Going forward, it needs to be confirmed whether grouper mariculture density and fish length have an impact on oxygen saturation (by comparing with daily mariculture work logs) and there is also a need for relative evaluation (by observing oxygen saturation at points distant from the floating cages). It will also be important to observe the tidal currents in order to evaluate water circulation inside the reef. Also, it will be essential to consider the impact that wind and waves have on observation data.

Moreover, in light of the fact that global-scale ocean circulation carries surface-layer water from the seas around Hawaii to those around Indonesia, it is essential to monitor changes in the marine environment not just from a micro perspective but a macro one as well. Thus, the authors plan to implement remote sensing via satellite. They further plan not only to observe marine environment elements like water temperature, but to do a more comprehensive evaluation of the cultivating site including measurements of the topography and geology of the sea floor. Also, they have plans to accumulate data from continuous observation and evaluate the impact the marine environment has on the growth and feeding behavior of fish and shellfish, thereby establishing maricultural technology for selecting optimal cultivating positions and depths and ensuring stable production. They will then expand this technology from Bali to the islands of Lombok, Sumbawa, and Sumatra.

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