Development of coastal water monitoring technology in Wakatobi regency, Indonesia

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Abstract. The coastal waters of Wangi-wangi Island in Wakatobi regency, Sulawesi Tenggara province has been under high anthropogenic pressure since 2003. This pressure can be measured from water quality parameters (temperature and dissolved oxygen). The aims of this research were to analyse water quality dynamics based on time series data for zonation, and to evaluate data utilization of water quality measurement in two points of depth. Coastal water dynamics were happened on west and east monsoon in 5 m and 25 m depth. Hypoxic and anoxic conditions were happened in 25 m depth, during west monsoon. The dissolved oxygen difference in 5m depth was approximately 2.5 mg L^{-1}, meanwhile in 25 m depth was 6.5 mg L^{-1}. The temperature difference from start to end was about three centigrade. There were no significant differences between 5 m depth and 25 m depth. The result showed that time series data were useful for fisheries management and dynamic coastal water spatial/zone planning. Western and southern coastal water zones are recommended for economic activity. Eastern and northern coastal water zones are recommended for conservation zone while other utilization zone has been allocated for sustainable fishing sub-zone.
Key Words: zone, time series, temperature, dissolved oxygen.

Introduction. Coastal water pollution has occurred in many parts of Indonesia (Hapsari et al 2017; Chandra et al 2014; Sidabutar 2012). The source of pollution in coastal waters (also occurs worldwide) is primarily the result of human activities (anthropogenic) (Elliot 2011; Rabalais et al 2009; Gray et al 2002; Moberg & Folke 1999; Howarth et al 2000). Anthropogenic pressure in the form of pollution is sourced from household waste, abundance of nitrogen and phosphorus (from agriculture, plantation, and livestock), factory wastes, river sedimentation, and oil/gas pipeline leaks. As population increases, anthropogenic pressure on coastal waters also increases (Jiang et al 2009; Rabalais et al 2009).

Coastal waters in Indonesia are defined as waters that are measured from the lowest coastline (flux) as far as 12 miles to the sea under Regulation no. 1 Year 2014 (State Gazette No. 5490). Typically, there are three (3) ecosystems in coastal waters, namely: coral reef ecosystems, mangrove ecosystems, and tropical shelves ecosystems (Pauli & Christensen 1995). The coastal waters of Wangi-Wangi island in Wakatobi Regency has only one type of ecosystem, that is coral reefs (Yulius et al 2015; Chandra 2012; Salim et al 2016).

Coral reefs in Indonesia are very potential as traditional fishing sites, especially for coral reef fisheries or demersal fish fishery (Wiryawan et al 2005). Coral reef-based fisheries have high species diversity and high productivity (Rose 2009). Coral reef require stable temperature, pH, light cycles, water flow, salinity and chemical composition to grow well (Rose 2009). As a primary producer (zooxanthellae in coral reefs), the existence of coral reefs is vital in marine ecosystems. Its existence will maintain the continuity of fishery activities and will directly related to economic activity. Maintaining coral reef ecosystems is as meaningful as maintaining fisheries and economic activities (Cesar et al 2004; Russ 1991).

Eutrophication will decrease coral reef growth and cause hypoxia as the initial parameter (Gray et al 2002; Sidabutar 2012; Moberg & Folke 1999). If this condition last long, there will be coral reef death (Rabalais 2009). The most easily observed example is that there are no coral reefs in the area around the river estuary in Wakatobi. Coral reefs are generally located in areas with low sedimentation abundance from land, high water brightness, and stable salinity.

According to baseline data by LIPI in COREMAP II project in 2006, coral reefs condition at Wangi-Wangi Regency was classified as good condition, more than 25% up to more than 75%, located in the northern and eastern part of the island. Furthermore, in 2011, the results of the COREMAP III project review showed stable condition of coral reefs in Wakatobi (World Bank 2012). This condition shows that the environmental burden of human activity has been very influential. While other regions showed a growing trend by 17% (Table 1). This means that coral growth in Wakatobi is obstructed by poor water environment and inadequate management (Rose 2009; Cesar et al 2004).

Table 1

The coral reef health (based on coral coverage) from LIPI's permanent plotting (Document of World Bank 2012)

No. of district	*2006*	*2007*	*2009*	*2010*	*2011*	*% Increase*
1. Pangkep (excluding Kalmas)	32	30	38	41	38	+19%
2. Selayar	32	34	36	43	45	+40%
3. Buton	34	36	38	30	41	+18%
4. Wakatobi	46	47	47	42	46	0%
5. Raja Ampat (excluding Batang Pele)	22	20	27	29	30	+33%
6. Biak	23	28	26	20	18	-23%
7. Sikka	18	17	13	21	25	+42%
Average	30	30	32	32	35	+17%

Coral reef conservation is important in order to maintain sustainable fisheries activities. Alcala (1988) stated that the value of fishery products associated with coral reefs in the Philippines were around 11-24 tonnes km^{-2} $year^{-1}$. If the area of coral reefs in Wakatobi regency is about 13,900 km^2, then the potential of coral reef related fishery would be 152,900-333,600 tonnes $year^{-1}$. Russ (1991) suggests that the level of sustainability of fishing in coral ecosystems is 10-20 tonnes km^{-2} $year^{-1}$. Thus, from the aspect of sustainable fisheries the catch value is worth of 130,900 tonnes $year^{-1}$.

The coastal waters of Wangi-Wangi Island in Wakatobi Regency, Southeast Sulawesi province have also been pressured by anthropogenic activities (Chandra 2012; Sopari et al 2014; Yulius et al 2015; Salim et al 2016). Wangi-Wangi Island (Figure 1) is one of four main islands in Wakatobi Regency, Kaledupa, Tomia, and Binongko within the Wakatobi Marine National Park (TNL), which has an area of about 1.39 million hectares. Wakatobi as TNL was based on the Ministry of Forestry Decree No. 7651/Kpts-II/2002, August 19th 2002. On December 18th 2003, Wakatobi was officially designated as one of the Regency in Southeast Sulawesi, formed under Regulation No. 29 year 2003, about the establishment of Bombana Regency, Wakatobi Regency and North Kolaka Regency (State Gazette No. 144). By becoming a Regency, economic activities were increasing in this TNL, especially Wangi-Wangi Island, as its capital.

The increasing economic activity pressures which occur in coastal waters indicating the need for management based on integrated model or zonation mechanism (internationally known as Marine Spatial Planning or MSP), as there are many failed managements based on sectoral approaches (Lubchenko 2010; Ehler & Douvere 2010). Some characteristics of MSP are: ecosystem-based, integrated, area-based, adaptive, anticipatory, and participatory (Ehler & Douvere 2010). MSP will create opportunities for people to collaborate and find solutions that minimize conflicts and environmental impacts.

In Indonesia, MSP concepts were adopted into regulation called Zoning Plans for Coastal Areas and Small Islands (RZWP3K) (Directorate of Spatial Planning 2013).

Several techniques of RZWP3K were used to conduct field surveys in order to collect data and information for the zoning plans of coastal waters of the Regency, namely: observation, sampling, measurement, interview, questionnaires and focus group discussion (FGD). The measurement and observation have not use biophysical parameters time series data. Generally, due to limitation of time and budget, only biophysical parameters are collected for 1-2 weeks, sometimes even only based on discussions which only conducted within three days. The RZWP3K process is not a scientific research but a public process (Ehler & Douvere 2010). However, the data and information used were obtained from research results, be it temporal, serial and spatial information.

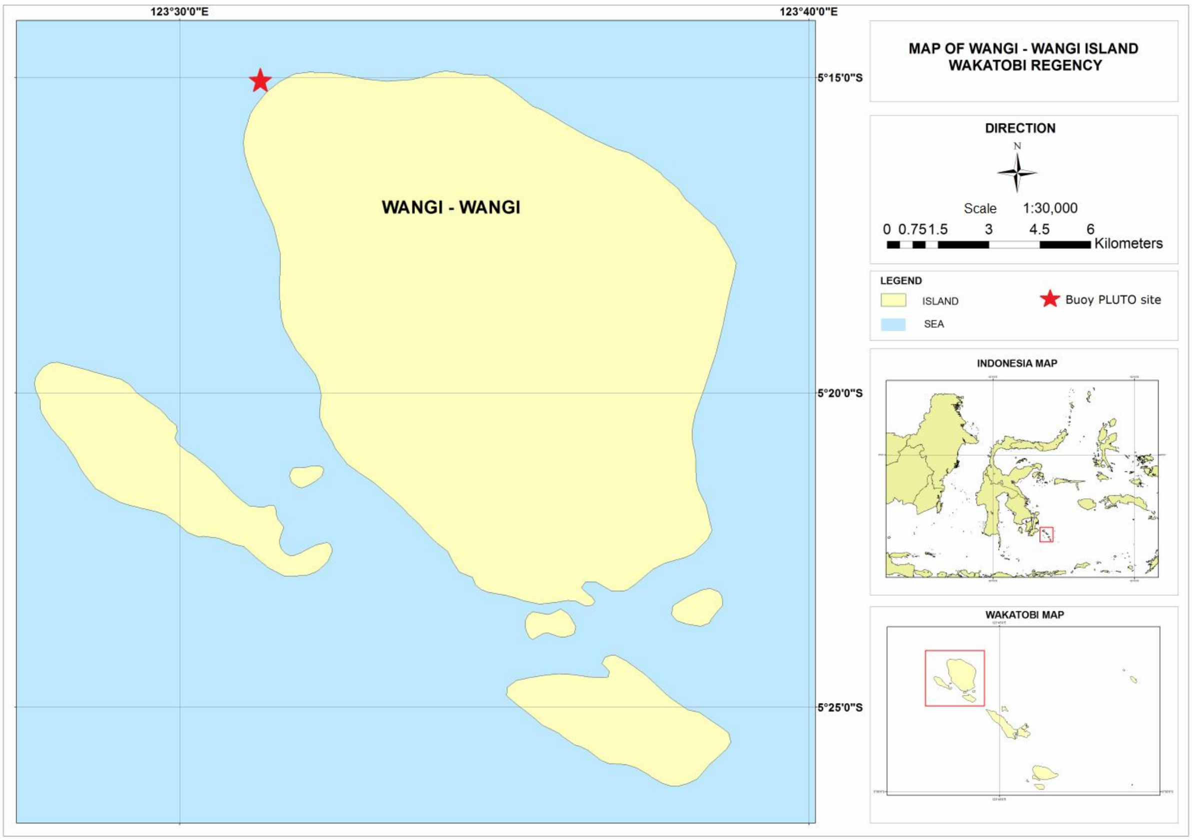

Figure 1. Wangi-Wangi island in Wakatobi regency, Southeast Sulawesi province, Republic of Indonesia. The PLUTO buoy deployment site near Waha Regency.

Water quality monitoring in time series has been conducted in reservoirs, lakes and ponds in Indonesia (Krismono & Astuti 2016; Chandra & Borneo 2016). The results proved to be very useful in the management of inland waters, especially in aquaculture (tilapia, carp and gourami). Water quality monitoring in time series also has been performed on seaweed cultivation in the village of Liya, Wangi-Wangi, in 2010 (Chandra 2012), with monitoring point on the surface to a depth of 1 m. The results showed a great benefit in the course of managing the cultivation period of seaweed.

Water quality monitoring in time series at one depth point (surface) has both advantages and disadvantages (Chandra 2012). The advantages are cheaper installation and operational costs, simpler production process and easier maintenance. While the disadvantage is that water parameters below are unreadable. These parameters can provide useful data and information to understand the ecological mechanisms of coastal waters and their impact (Fiorelli 2009). Therefore, it is necessary to test the utilization of water quality data at two points of depth.

The research aimed to analyse the dynamics of water quality based on time series for fishery aspect, and also to evaluate the utilization of water quality monitoring data at two point of depths. The utilization of time series data in order to manage coastal waters area, has never been performed in Indonesia. To achieve the objectives of this research, design and engineering of water quality monitoring equipment will be conducted. This study has important innovation factors as it seeks to assess new issues - by utilizing time series data - applied to the analysis of aquatic dynamics and the impact on coastal waters zonation plans and also do the innovation testing toward the tools used.

Material and Method

Materials. Material used in this research was PLUTO buoy time series water quality monitoring equipment which has been patented in Indonesia, tested and used in many places (Chandra et al 2014; Krismono & Astuti 2016). PLUTO buoy were equipped with temperature, salinity, pH and dissolved oxygen (DO) sensors installed by using Tripod sensor from Ponsel (French manufacturer), at 5 m and 25 m depths. Data collection was performed in several stages. The first stage was to do the engineering of PLUTO buoy for two depth monitoring (5 and 25 m). The calibration of the Tripod sensors device from the Ponsel (French) in the PLUTO buoy was performed by testing it with a similar tool from the Pro-DSS brand from YSI (USA). Second stage was buoy deployment located on $5^{o}15'155''$ latitude and $123^{o}32'528''$ longitude. The series of sensors at each depth were: 5 m (DO, temperature), at a depth of 25 m (DO, temperature), by using Ponsel brand. The period of study was from May 2015 until February 2016. It took five months to designed and manufactured all the equipment before the buoy be deployed.

Data analysis. Time series data analysis was performed using only two parameters (temperature and DO). The data were processed by using Microsoft Excel software. The result of the processed time series data were then preceded to the discussion. Recommended zonation for coastal and small islands on biophysical time series data were based on technical guidance of RZWP3K compilation (Directorate of Spatial Planning 2013; Ministry Decree No. 51/2004).

Results and Discussion. Design and engineering work were performed in Jakarta and Wangi-Wangi regency. The deployment location of water quality monitoring buoy with two coastal depth can be seen in Figure 2.

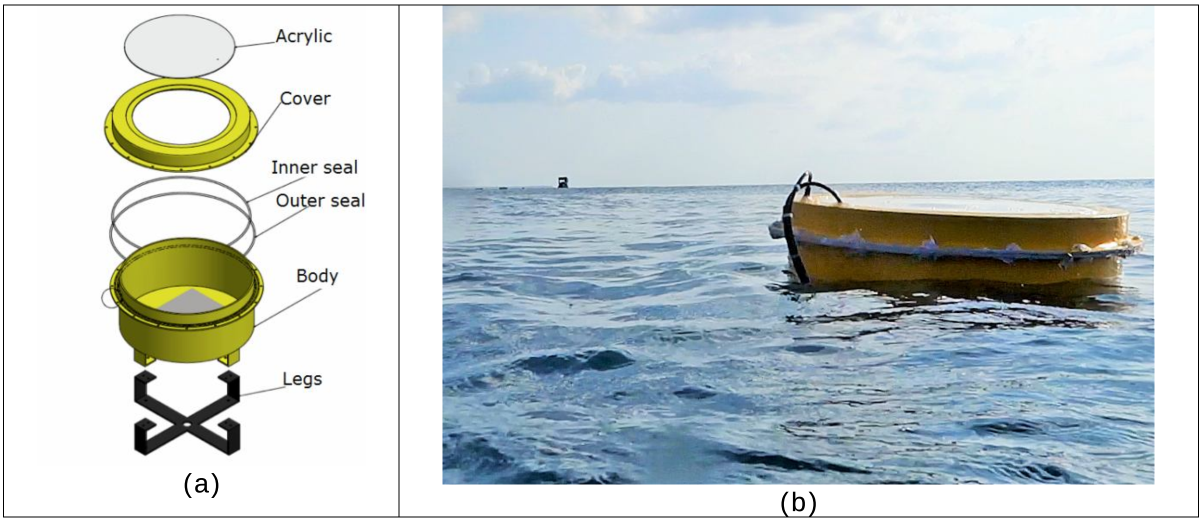

Figure 2. PLUTO buoy: (a) Design for two depth monitoring; (b) After deployment.

Data of temperature in time series at 5 and 25 m point of depth can be seen in Figure 3. Temperature difference between the two points of depth is not too large statistically due to relatively the same standard deviation for 5 months (September 2015 - January 2016). Time interval for temperature measurement was taken in every one hour (60 minutes). The recorded data were amounted to 2.595 in total. At 0-25 meters depth, water temperature was relatively stable because it is still in mixed layer zone. This zone is affected by wind, waves and currents and longshore current (Stewart 2008). In addition, the location of PLUTO buoy deployment is still in coastal waters with topographic shape of lagoon that the dynamics of the waters is relatively stable (Davis & Fitzgerald 2004).

During the transition of east monsoon to west monsoon, for two months, temperature tended to increase by 30^{o}C (Figure 3). This is influenced by the movement of currents and monsoon in eastern waters of Indonesia. Gordon (2005) mentioned that in west monsoon, the surface temperature in eastern waters of Indonesia tends to increase. Seasonal shifts in sea surface temperatures is affected by Ekman upwelling process in east monsoon (southeast), along the Sunda archipelago and Banda sea, resulting to lower water temperatures. While on west monsoon (December-February), the water surface temperature in Wakatobi becomes higher compared to southeast monsoon. Qu et al (2005) stated that sea-level temperatures occur in the Banda Sea, Arafura, Timor and South China Seas with a value of more than 40^{o}C from the east to west monsoon cycle.

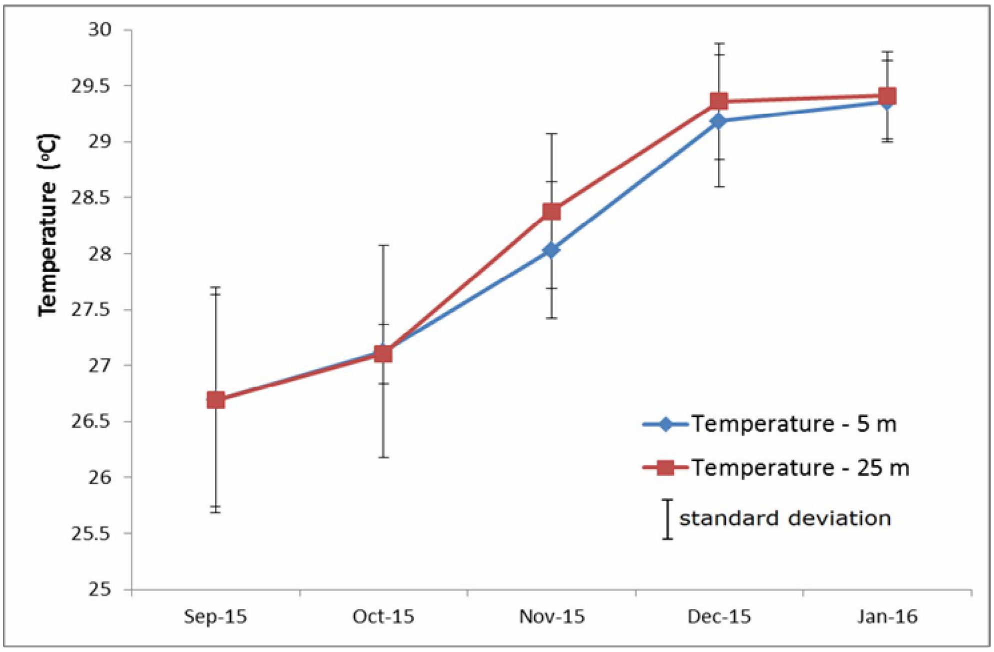

Figure 3. Average temperature and its standard deviation on 5 m and 25 m depth for 5 months (September 2015 - January 2016).

DO monitoring time series data at 5 and 25 m depth is shown in Figure 4. Effect of depth difference to oxygen content value also happened in coastal waters of Wangi-Wangi Island. Similar conditions have also occurred in the United States (Rabalais et al 2009; Howarth et al 2000; Kite-Powel 2009), Jakarta (Sidabutar 2012) and Pekalongan (Chandra et al 2014). The measurement difference at the beginning and the end is approximately 2.5 mg L^{-1} for a depth of five meters. As for measurement different at a depth of 25 meters, the gap is greater, which is approximately at 6.5 mg L^{-1}.

The self-assembled water monitoring equipment named PLUTO buoy has limitations that it cannot measure the depth of water in thermocline layer. This layer is very important and influential for fish habitat (Simbolon et al 2009; Tadjuddah et al 2013). On the other hand, the water mass has a higher density that becomes a trap for suspended sediments. These sediments will be a great advantage if the suspension is organic material which will be the support for primary producers.

Inadequately managed coastal waters, where high nitrogen in the form of NO_3 derived from the mainland, can be death zones for living biota (Rabalais et al 2009; Howarth et al 2000; Sidabutar 2012; Chandra et al 2014). This zone is indicated by very low DO value (anoxic: 0-2 mg L^{-1}) in the waters. Generally, harbor pool area has changed into a death zone due to the absence of waste management sourced from ships or from the mainland (Chandra et al 2014; Ministry Decree No. 51/2004).

Hypoxic (2-4 mg L^{-1}) and anoxic conditions occurred at a depth of 25 m as the waters begin to be affected by west monsoon in December-February (Gordon 2005; Wyrtki 2005). Increased rainfall causes waters to become mixed with sediments and leads to a decrease in DO content. While in east monsoon, in June-August, where the rain is rarely happened resulting in the relatively constant DO content (Figure 4). Based on this quantitative measurement data, coastal waters of Waha can be used as a tourism zone in east monsoon. While on the contrary, this area is not suitable for tourism zone in west monsoon (Table 2).

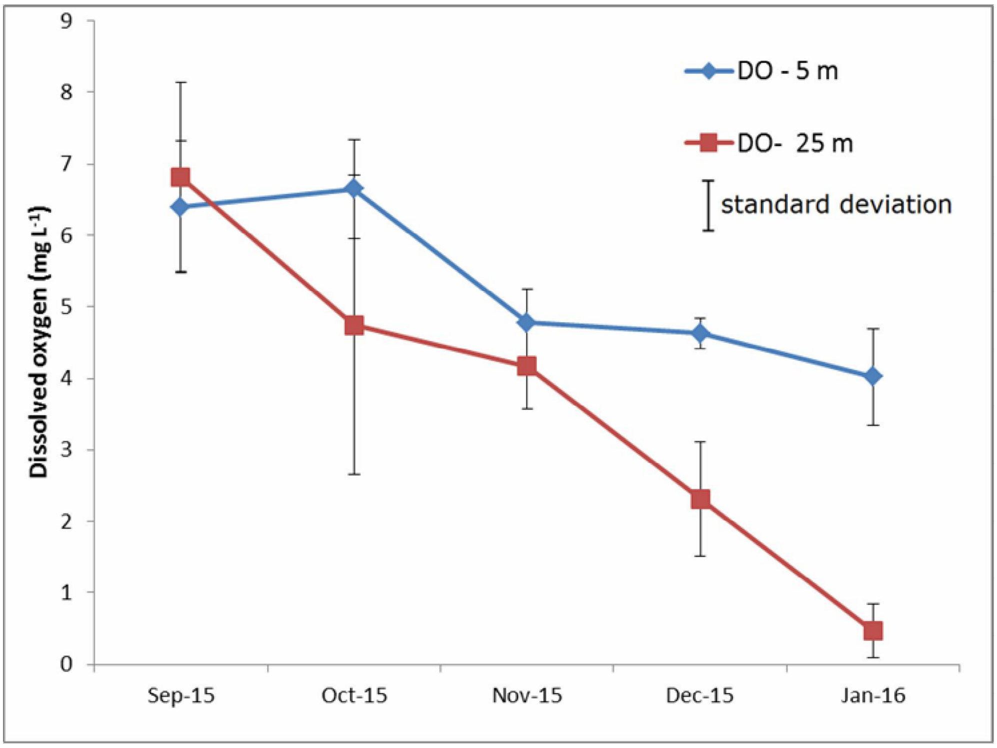

Figure 4. Average DO and its standard deviation on 5 m and 25 m depth for 5 months (September 2015 – January 2016).

Table 2

Resume of sea water quality standard from Decree of Ministry of Environment no. 51, 2004

Parameter	*Unit*	*Water Quality Standard Criteria*		
		Harbour	*Marine tourism*	*Marine biota*
Temperature	^oC	Natural	Natural	28-32
Salinity	ppm	Natural	Natural	33-34
DO	mg L^{-1}	-	> 5	> 5
BOD_5	mg L^{-1}	-	10	20
TSS	mg L^{-1}	80	20	80

One method of coastal waters management is through zoning. Zoning is a form of space utilization engineering by determining the functional boundaries in accordance with the potential of natural resources, carrying capacity and ongoing ecological processes, as a whole in coastal ecosystem (Directorate of Spatial Planning 2013). These three aspects must be considered in the determination of zonation in Wangi-Wangi Island using time series data as it is commonly known that coral reef is the main resource of Wangi-Wangi Island coastal waters. These coral reefs live from the surface of the waters up to a depth of 30-40 m where sunlight can still penetrate. Water carrying capacity to maintain coral reef existence is temperature, pH, turbidity and stable salinity (Ministry Decree No. 51/2004; Kite-Powell 2009; Rose 2009). By maintaining water quality, the sustainability of coral reef ecosystems will be ensured, which will also ensure the sustainability of coral reef fisheries worth of 11-24 tonnes km^{-2} $year^{-1}$ (Alcala 1988) with a sustainable potential of approximately 10-20 tonnes km^{-2} $year^{-1}$ (Russ 1991).

According to the result of baseline survey in 2006, the coral reefs are still good in the north and eastern part of the island. This is due to the conditions of the water in these area are still good and in accordance with the Ministry Decree No. 51/2004. Rabalais et al (2009), Kite-Powel (2009), Sidabutar (2012) and Chandra et al (2014) stated that correlation of anthropogenic pressures toward coral reef conditions are inversely proportional. If the anthropogenic pressure gets higher, then coral reef cover condition will be lower. Thus, good coral cover conditions in the northern and eastern parts of Island in 2006 are still relevant if related to the distribution of water parameters in 2016. Unfortunately, there is no time series data which can indicate whether there is a major change in the span of 10 years. Water parameters at the time of the survey by COREMAP in 2006 (World Bank 2012) is obviously very different from the year 2016 where population and economic activity has rapidly increased.

According to Borja et al (2016), good data collection criteria are transparent, repeatable for both measuring tools and measurement methods, and easily communicated to all parties (scientists, policy makers, managers, government and society). The temperature and DO parameters are parameters that are transparent, repeatable and easily communicated to all parties. Chandra (2012) has carried out measurements of temperature, salinity and DO parameters in the Liya region of 2010-2011, and recorded the dynamics of water temperatures due to the influence of east and west monsoon. In the west monsoon, ice-ice disease in *Eucheuma cottonii* seaweed will be increased due to the decreasing temperature and salinity of the waters causing loss for seaweed farmers.

Looking back at Wangi-Wangi island map in Wakatobi regency and population distribution (Figure 1), eastern and northern waters territory of Wangi-Wangi Island should be maintained as coral reef ecosystem conservation zone (sustainable fisheries). Whilst western and southern waters territory should be maintained for economic and fishery activities (may also be called sub zone of aquaculture).

Conclusions and Recommendation. Time series data has been proved to be of great significance. The results of the measurements showed that the dynamics of waters can be read in the presence of time series data and also showed different values during east monsoon and west monsoon. In-situ data of time series showed differences in biophysical parameters (temperature and DO) in both east and west monsoon. In west monsoon, temperatures were higher but lower DO. Temperatures were approximately $3^{o}C$ higher (at both depths) and DO contents were 2.5 mg L^{-1} lower (in a depth of 5 m) and 6.5 mg L^{-1} lower (in a depth of 25 m depth). The results also showed that the specially designed tools (innovations) were useful for the measurement of waters parameters in time series, work well and useful. Recommended zoning for Wakatobi Regency is the northern and eastern part of the coral reef ecosystem conservation zone (for sustainable fishery zone), while the west and south are recommended for economic and sub zone of fishery activities (aquaculture).

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