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Inner Water Characteristics of Anambas Island, Riau Province-Indonesia

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Abstract: ***Anambas archipelago which consists of 255 islands located in the southern South China Sea (sSCS) and parts of Riau province. This study aims to provide an initial overview of the Anambas's water characteristics on East Monsoon (EM). Data was obtained from two primary surveys that conducted in 2012 and 2013. First survey collected a number of 20 stations which focused to the northeast region of Anambas that consists of Mengkian Island, Mandariau Island, and Penjalin Island. Second survey collected 16 stations which represented the whole inner water of Anambas. The depiction was done with primary data collection, calibration and data processing, visualization, and analysis. The results show that the Anambas water is the shallow one with the average depth of 40 meters. The tidal rangeis approximately 1.35 meters and the dominant ocean current is southward current that moves to KarimataStrait and Malacca Strait. The ocean current condition of Anambasis also affected by the water mass that originates from the South China Sea (SCS), Java Sea, and Malacca Strait. The other water properties were like ocean surface temperature (28-32.5^{0}C), absolute salinity (29-35 PSU), brightness(10-16 meters), pH (6.8-8.8 units), and dissolve oxygen(4.4-6.8 mg/L). The biological property such as the abundance of plankton varies and dominates by Thallasionema and shows significant correlation with the ocean current pattern.***

Keywords: Anambas Archipelago, East Monsoon, Water Mass, Inner Water, Oceanographic Condition.

1. Introduction

The existence of islands in Indonesia will determine the characteristics of oceanographic conditions around it. The island and basin will act as the secondary force that changed the direction of bulk water mass. Geographically, the islands are located in the southern South China Sea (sSCS) which is adjacent to the Natuna and Tanjung Pinang and part of the Riau Province (02°10'0"-03°40'0" N and 105°15'0"-106°45'0" E). Anambas has 255 islands and vast waters reach 70% of the total area is believed to have a unique and complex ocean characteristics. These island will give much information about water mass because the linking to Indonesia waters and South Cina Seas. However, there is limited primary ocean data that has been done in this inner area. This area becomes one of Fisheries Management Regional of Indonesia Republic (WPP-RI 711) and Indonesia Archipelago Sea Channel (ALKI 1). Moreover, as geopolitics area, these islands also have five outer islands that bordered with Malaysia, Singapore, Cambodia, and Vietnam [1]. In the north of these islands, there is a mining zone which is currently in the exploration stage. This area is also a migration route of some marine biota such as sea turtles and Napoleon fish.

Based on the geographical location and the condition of the islands, this region has a huge potential to be developed. In 2012 and 2013 spatial zoning management study has been conducted by the Ministry of Marine and Fisheries (KKP-KP3K) which appoint Anambasas a priority area for fishery and tourism by enclosing the conservation area as a measure of the diversity of flora and fauna [2]. However, with the region consist of 70% water is a challenge in establishing sustainable management [3]. In connection with both of those which are related to each other gives an overview of the importance of oceanographic conditions in the waters around Anambas Islands. In addition, oceanographic conditions in Indonesia are very much influenced by local factors.

Characteristics of the waters in Anambas region are very unique and complex because of the basin and land that stretches from north to south, the input and output of water masses, wind pattern, and nutrients concentration. The topography and basins act as a secondary force which affects the movement of water mass [1]. Generally, the condition of the waters in the Anambas is influenced by the South China Sea (SCS), the water masses from Java Sea and Malacca Strait. The dominance of the three water masses will be influenced by the ebb and flow that comes from the Pacific Ocean. Due to this area, then it is likely to undergo changes in the oceanographic dynamics. Force of water masses will bring nutrients to dynamically operate the food chain in the water column. This region (SCS) is a large marine ecosystem with a specific and unique oceanographic characteristics, biography and ecology. Most of the southern part of SCS is atSunda Shelf and has shallow water characteristic(depth< 200 m). Itis also influenced by the oceans and land through the input from rivers that flow from the surrounding islands. The southern part of SCS isa sea region which belonging to

Indonesian waters. In the northern part, there are a canal basin and also Palawan Channel which is deeper (depth> 1000 m). It is surrounded by a very shallow continental edge and exposure to China, Vietnam, Cambodia, Thailand, Malaysia, Indonesia, and Philippine [4].

2. Study Area

Study area of this research is bounded on the Anambas region with is shown in Figure 1. Waters territory covers nearly 70% of the islands. Most of human activities conducted in north of the islands which was in Tarempa (Siantan island) and Matak island. Air transportation which integrates Anambas to the nationwide air traffic was in Matak Island facilitated by the airport of Conoco Philips company. However, in a few years based on the spatial planning, the air transportation facility will be moved to the south in Jemaja Island.

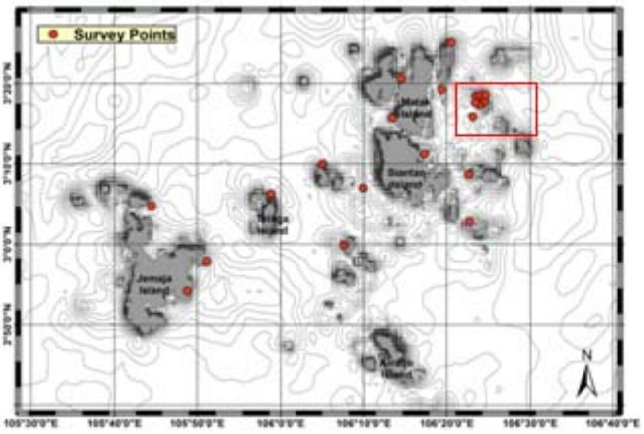

Figure 1: Research location (red box: 2012 survey)

Area in North of Anambas is SCS, in the east areNatuna and Borneo island, south is Java Sea, in the west are Cambodia, Malaysia, Vietnam. Spasial and temporal analysis based on sampling stations in inner island.

3. Methods

This study emphasized with the primary survey which was conducted in 2012 on the three islands namely Penjalin, Mengkian, and Mandariau Island (fig. 1, red box). Station was located in the northeast Anambas, while in 2013 there were 16 stations that represented the overall Anambas inner waters (red dot). In order to complete the overview of water characteristics, data from World Ocean Database (WOD) was used to indicate the temperature and salinity of the water masses patterns. Ocean currentwas measured by using a floating drogue (Lagrangian method) and also with the current meter type AOTT 100 mm diameter; pitches 0.125 (Eularian method). The depth was measured by using the GPS Map Echosounder (then combined with GEBCO data) and the other physical parameters were measured by using portable instruments. The method used on plankton sampling was pump-up method. Sampling was taken by using standard plankton net with 20 µm of mesh size. The number of seawater taken into the net was 100 liters for each measurement and the number of seawater filtered was 150 ml. Lugol was used as preservative compound on each bottle sample. The bottle sample was stored in cool storage until it was taken to laboratory to be counted using Sedgwick-Rafter counting cell. Enumeration carried out under a light microscope at a magnification of 10x10, a calculating device [5]. Plankton identification was used several identification books [6]-[9].

Table 1: Datasets used for this research

	Year	Regions	Parameters	Details
1.	2012	Penjalin Island, Manda Riau Island, andMengkian Island	ocean current, temperature, and salinity	20 stations
2.	2013	Inner Anambas Water	ocean current, temperature, and salinity	16 stations
3.	2013	Inner Anambas Water	DO, brightness, pH, and air temperature	16 stations
4.	2011	Matak Island	tide observation	13 days
5.	2011	Matak, KepulauanAnambas	tide prediction	Tidal Model Driver (TMD)
6.	1941-2013	South China Sea, Anambas Islands,Karimata Strait, and Malacca Strait	ocean temperature and salinity	World Ocean Database(WOD) 2013

4. Results

The first characteristic to determine the profile of water in Anambas is to get the depth countours. Depth profile in inner of Anambasisbetween 5-60 meters, but outside the islands isrising above 100 meters in the south and more than 1000 meters farther to the north. Contour basins vary greatly and is one factor contributing to the complexity of the mass movement of water systems in these islands (Figure 2). These complex basin give the second force to the direction of water mass. Surveys conducted in 2012 and 2013 resulted the depth around 40 meters in the area of the inner islands. But beyond the waters of the northern Anambas, the depth increases up to 2500 meters [10]. These profile made the water mass also have warm and shallow waters.

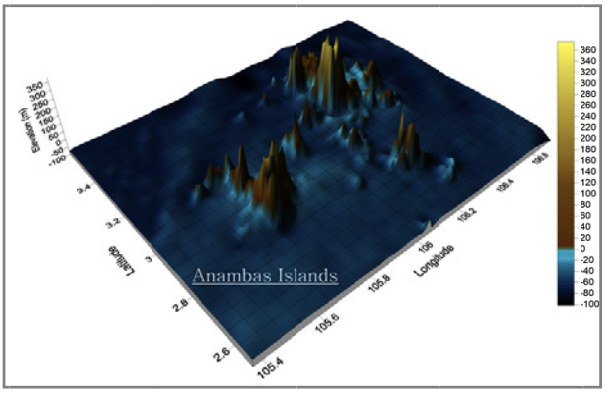

Figure 2: Topography visualization of Anambas Archipelago

4.1 Physical-Chemical Water Properties

Anambas Islands which is relatively shallow, has the water temperature varies of 29°-32°C, but is similar to other areas outside the isle. Due to the shallow waters, the vertical temperature pattern is not much different. Uprising temperature distribution patterns in the waters of the SCS,

there is a layer of mixed water masses (homogeneous) with a thickness varying between 25 and 44 m depth [11] .In EM, warmer surface temperatures in the west where the currents coming from SCS will be forwarded to the west due to the wind.The same pattern is obtained from the horizontal salinity profiles in which the part has been gathering in the islands with a range between 27-34 SA (Figure 3). The temperature of surface waters is affected by the temperature of the atmosphere in which the measurements were carried out in 2013 showed that there was no significant difference between the temperatures of the atmosphere with the SST. Lowest SST was 28.9°C, while the air temperature is 31°C.

Table 2: Correlation between Sea Surface Temperature (SST) and Air Temperature (AT)

St.*	Parameters		St.*	Parameters	
	SST (°C)	AT (°C)		SST(°C)	AT(°C)
1	30	32.3	9	28.9	31.5
2	29.7	32.0	10	29.5	31.5
3	31.8	33.5	11	29.6	31.5
4	29.8	32.0	12	30.1	32
5	29.6	32.5	13	30	33
6	30.9	31.2	14	30	33.2
7	31	32.0	15	29.2	31.9
8	30	32.5	16	29.2	31

*St.is stands for Station
**Correlation number between both parameters is 0.474

In the period from July to September a little hot air temperature (approximately 32°C) where the wind is blowing southeast and rain down rather a lot while the period from October to December wind blowing west/north [12]. Spatially, higher temperatures are in the western part of the value of about 32.5^0 C. This may be caused by the movement of water masses originating from the SCS. Besides that the temperature inside the territorial waters of the islands tend to be warmer than the outside waters (Figure 2a). Salinity patterns slightly different from the pattern in which the temperature in the northeastern region of lower salinity of about 28 PSU. This is caused by the mass of fresh water from the river, but the pattern in other parts look almost the same (Figure 2b). In the MT the mass of water around these islands generally have a low salinity because it has undergone dilution of the rivers surrounding islands but instead on the west season, high -salinity water mass is transported by Armondo of South China Sea through the entrance to the Strait of Natuna Islands Karimata and further towards the Java Sea [13]. In waters adjacent to Anambas salinity ranged from 32-36 ppt [14], [15].

Water transparency can be seen in Figure 2c which shows that these waters are very clear with the range of 6-17.7 meters. Water areas with the lowest brightness conditions contained in the southeastern islands where it is influenced by the condition of the bottom waters with sandy mud substrate. For pH conditions as one of the chemical parameters of waters ranging between 6.75-9 units and higher pH pattern is in the southern islands.

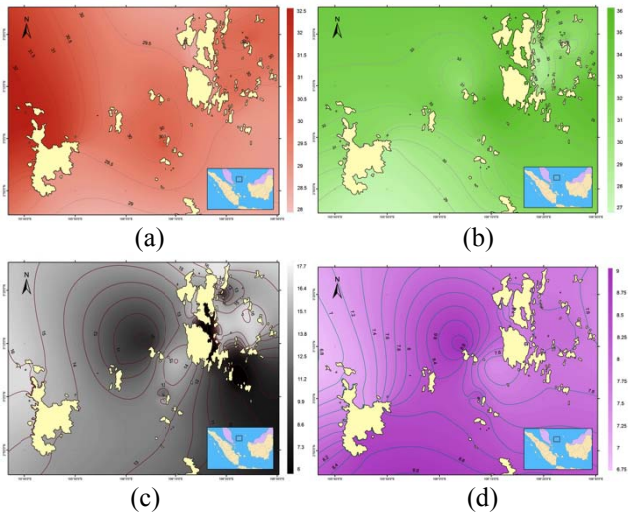

Figure 3: Spatial visualization of water properties. (a) SST; (b)salinity;(c)transparency; (d)pH

Characteristics waters in September compared with other seasons seen in Figure 4, where the mass of water in September is dominated by water masses originating from the CSF. The influence of the Java Sea just a little bit because it is already mixed between Natuna and Anambas. Water masses are of the Strait of Malacca is connected with the tide currents that along east-west pattern.

Different conditions found in other seasons in which the dominance of the Java Sea and the Malacca Strait is more visible. This is possible due to a decrease in the speed of the SCS due to the change in momentum that comes from the Pacific Ocean. However, it appears that almost every season, the third source of water masses characterize the Anambas waters.Conditions in the waters Anambasa semi-enclosed waters with lots of channels causes the circulation in the northern and southern parts of the South China Sea a little different. The results in September showed that one of the changed direction of the current basin conditions and topography, are islands, where current direction is determined by the presence of the islands.

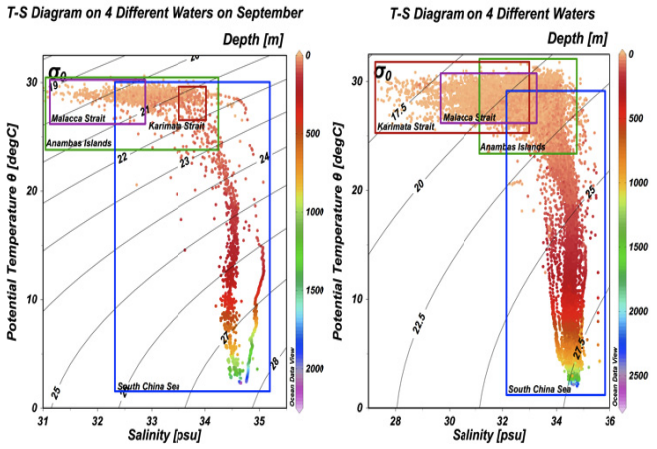

Figure 4: T-S Diagrams on four different waters. (a) filtered data on September; (b) all the time data

Flow conditions at the surface and at a depth of 0.4d is not much different, where this is due to the shallowness of the waters. The most rapid flow conditions obtained in the southwestern region of the speed of 0.22 m/s. Flow patterns

which occur predominantly south-west, where the current direction is derived from the Natuna islands mixed with water masses with SCS. Then the mass of water from the ocean mixes with the Strait of Malacca Java pressing upward and deflected by the Malay basin which then turn directions to Anambas [16]. The EM mass of water from the Java sea will rise to the SCS in Natuna Islands [14]. However, the meeting then divert the water to the mass majority Anambas.In Fig. 5 the correlation between Model and Observation results of tide level is 0.96 (highly related) and also the RMS (Root Mean Square) of the difference between both results is 0.24 which also can be seen as the green line (residual). So, from this statistic results, it can be said that using TMD (Tidal Model Driver) on this research to get tidal pattern in Matak is valid.

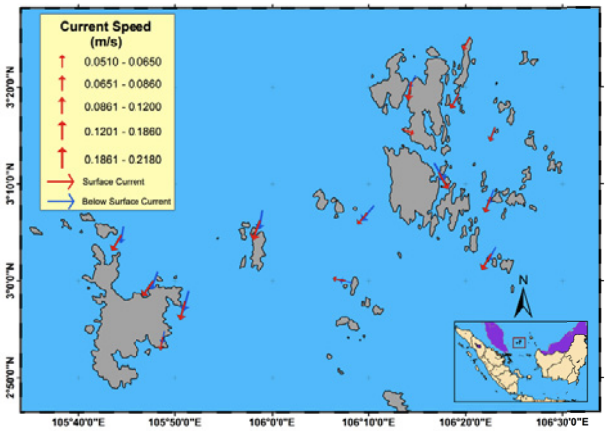

Figure 5: Ocean current pattern at 0.2d (red line) and 0.4d (blue line)

Tidal pattern in Anambas Island when the measurement was doing can be looked at Fig. 5 the range of tidal between ebb and flood is 1.35 m with the highest water level is at 0.68 m above MSL and the lowest water level is at 0.67 m below MSL. The standard deviation (std) of this tidal pattern is 0.44 m. It means that normally the water changed about 0.44 m above or below mean sea level.

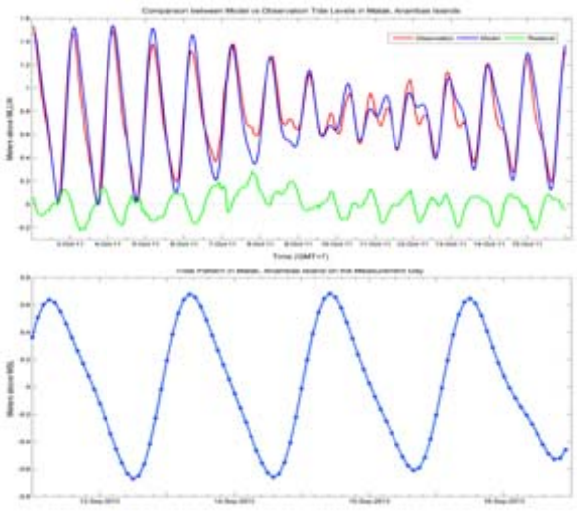

Figure 6: Tidal pattern in Matak Island, Anambas. (a) Model vs. observation on tide levels in September 2011; (b) Tidal pattern when conducting field survey

The highest influential tidal constituent in Matak, Anambas Islands, can be seen from the Table 2 K1 as a Luni-solar declinational diurnal constituent is the highest one. Then it followed by Lunar declinational diurnal constituent (O1) and Principal Lunar semidiurnal constituent (M2). With K1 and O1 higher than the others, so the tidal type is belonged to the single type or diurnal. Also it is proven by Formzhallnumber which is in the numbers of 4.98 that defined the tidal type as the single type.

Table 3: Tidal constituent's (TC) number resulted from model

TC	Number	TC	Number	TC	Number
M2	0.1226	K1	0.4425	MF	0.0049
S2	0.0298	O1	0.3175	MM	0.0060
N2	0.0283	P1	0.0944	M4	0.0046
K2	0.0063	Q1	0.0537	-	-

4.2 Biological Water Properties (Plankton)

SCS holds a very important role in distributing nutrients into waters Anambas. Warm waters make this region as a region-fish commercial fishing. This is as indicator that this waters have biodiversity of nutrient. As a result of differences in the characteristics of the plankton species were found also varied, but dominated by *Thallasionema* spp., *Thallasiothrix*spp., and *Ceratiumfurca*, which are the types of phytoplankton that is commonly found ranging from estuaries to offshore.Seasonal flow patterns and nutrients from run-off effect on the distribution of phytoplankton causes of HAB species found in the study site [5]. In the southwest region are only found Pleurosigma not found in other regions. However, this measurement is only an instantaneous measurement. Type *Rhizosolenia* spp. is the type found in almost all stations (Figure 7).

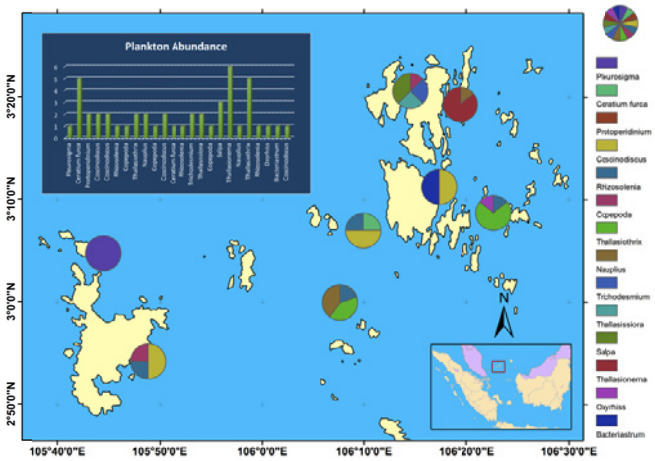

Figure 7: Plankton abundance and distributions

5. Conclusion

Physical conditions, chemistry, and biology in waters Anambas very complex because it is influenced by three main water masses dynamics caused by the mixing of water masses due to tides, currents, and wind. Form of water mass input either from the north and south affect changes occur to temperature, salinity, pH, and brightness. These fluctuations occur daily, seasonal, and yearly, and local factors affect the salinity. There is a difference in the characteristics between the islands at the north and south islands. Plankton sampling

was carried out on a limited and can still be done with a long sampling time is longer and more stations due to the structure of this community is still very limited.

6. Acknowledgment

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