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The Identification of the Morphological and Hydro-Oceanography Characteristics of Kaledupa Island

Al Azhar[a*], Ario Damar[b], Dietriech G. Bengen[c], Agus S. Atmadipoera[d], [a]LPPPTK KPTK, Ministry of Education and Culture, Indonesia, [b]Department of Aquatic Resources Management, Faculty of Fisheries and Marine, [c]Department of Marine Sciences and Technology, Faculty of Fisheries and Marine Sciences, Institut Pertanian Bogor, Indonesia, [d]Center for Coastal and Marine Resources Studies, Institut Pertanian Bogor, Indonesia, Email: [a*]rahzala023@gmail.com

This study aims to identify the morphology and hydro-oceanography characteristics of Kaledupa Island as small island management input. Data used were Landsat 8 OLI Imagery (2016) and Worldview 2 (2013) to define beach typology; SRTM (Shuttle Radar Topography Mission) data was obtained from ftp:/topex.ucsd.edu/pub/srtm30_plus/srtm30/data/ to determine land elevation and its slope, and seafloor topography; and dataset (in 2017) downloaded from http://marine.copernicus.eu/ to illustrate hydro-oceanography parameters (currents, waves, and sea level temperature). Data processing applied were Global Mapper 18, Surfer 13, and ArcMap 10.3 (to analyse SRTM data); Ferret version 6.02 and WRPlot View (for currents, waves, and sea level temperature). Results showed that the northern part of the island consists of sandy and vegetated beaches (mangrove), whereas the beach on the southern part are dominated by rocky and sandy beaches; land elevation ranges between 0-180 m; land slope ranges between 0 to 53.7o; bathymetric value ranges from 0 to -1,800 m; the current speed reaches 0.2 m per second in July; the highest waves occurred in June at the range of 0.70-0.80 m; while the highest surface temperatures (around 30.5oC) occur from April to May and November.

Key words: *Kaledupa Island, morphology, hydro-oceanography, small island.*

Introduction

Kaledupa Island which belongs to Wakatobi National Park (WNP) is categorised as a small island. Many experts define a small island based on its width. Dahuri (1998) and Hess (1990) Set examples were made by limiting the small island's width of no more than 10,000 km^2. Furthermore, Falkland (1995) defines small island as having a width of 5,000 km^2; Ongkosongo (1998) claims that a small island has a width of 2,000 km^2. In addition, very small island's width is limited to no more than 1,000 km^2 and a width of less than 3 km (Hehanusa 1995; Falkland 1995). UNESCO (1991); Bengen *et al.* (2012) state that a very small island has size of no more than 100 km^2, and the width is 3 km.

Based on its characteristics, a small island is categorised as an oceanic island, consisting of two kinds of islands, those as volcanic islands and coral islands (Dahl 1998; Salm *et al.* 2000; Bengen 2006). A volcanic island is formed due to volcano's activities (Lozano-Bilbao *et al.* 2018; Ramalho *et al.* 2013; Palomino *et al.* 2016; Quartau *et al.* 2018), while a coral island is formed due to the geological process of coral reefs (Woodroff *et al.* 2005; Barry *et al.* 2007; Kench *et al.* 2014).

A small island has unique biogeophysical characteristics, such as being isolated from other habitats, so that it is insular, having low terrestrial biodiversity, high marine biodiversity, small weather variety but fast changes, and having wider waters area than the land areas (Dhal 1998; Bengen 2002). Furthermore, freshwater resources are limited, both from the surface water and the groundwater (Herrera & Custodio 2014; Martinez-Moreno *et al.* 2016; Prada *et al.* 2016).

According to the size and characteristics of a small island, Kaledupa Island is certainly sensitive and susceptible to the external effect, both natural effect (Woodroffe 2008) and human activities (Wu *et al.* 2014). The islands' formation process, (Quartau *et al.* 2018), morphology (Mandlier & Kench 2012), and hydro-oceanography, including currents (Webb & Kench 2010), waves (Jeanson *et al.* 2013; Smithers & Hoeke 2014), sea level temperature and wind condition, is tightly correlated and affects the island's presence.

Due to such conditions, the morphological characteristics (beach typology, land elevation, slope and seafloor topography) and hydro-oceanography (currents, waves, and sea level temperature) of Kaledupa Island is important to be reviewed for the formulation of small island management. Thus, the potential and susceptibility of Kaledupa Island can be ensured so that continuous utilisation of the island can be performed.

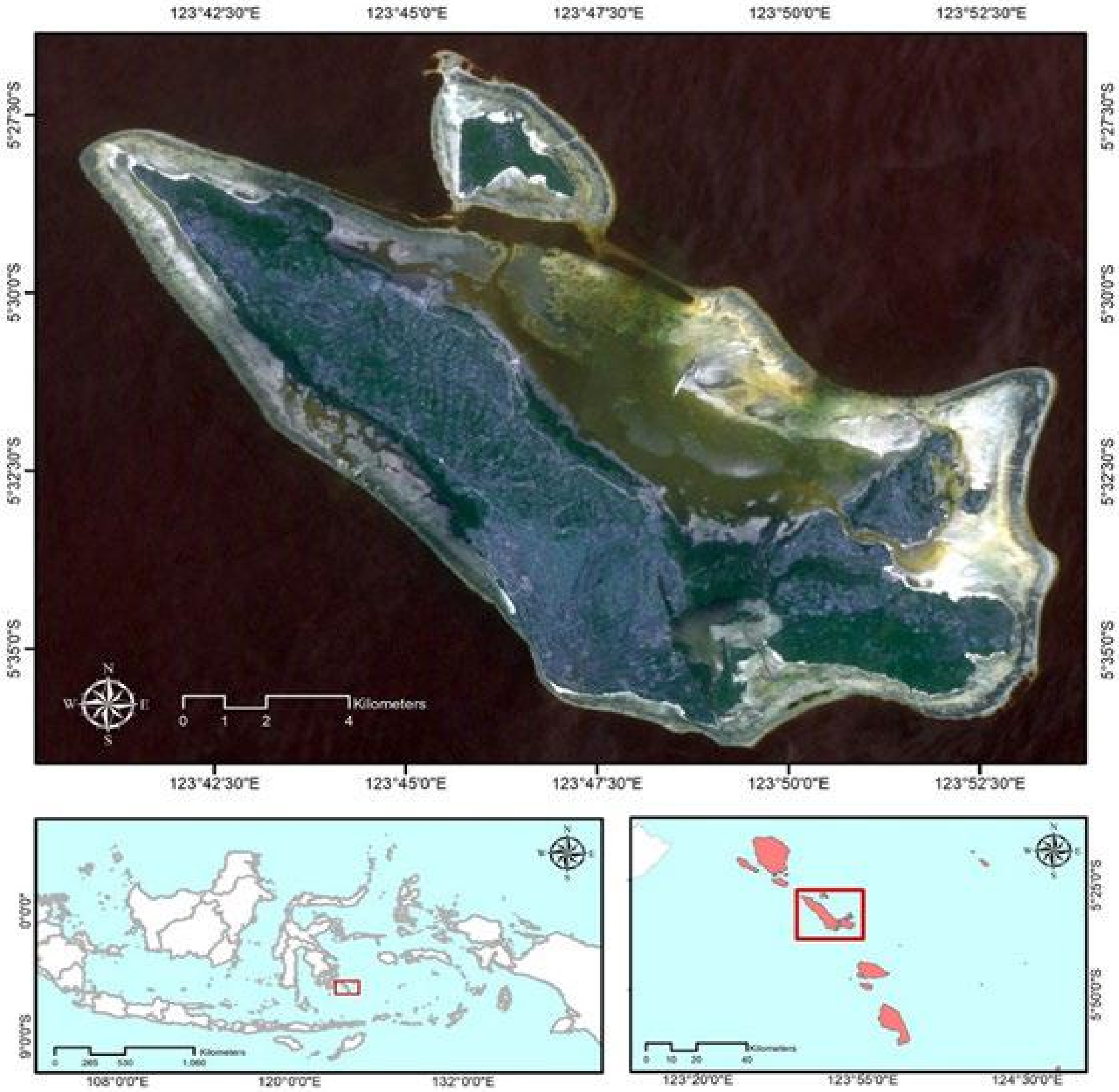
Study Area

Kaledupa is located in coordinate 5°27'4" - 5°37'10" SL and 123°40'35" - 123°54'42" EL (see Figure 1). The zonation system is used to manage the area, done by Wakatobi National Park Centre, under the Ministry of Forestry. Furthermore, COREMAP (*Coral Reef Rehabilitation and Management Program*) is also utilised as coastal resources conservation program, managed by the Ministry of Maritime and Fisheries and cooperated with the government of Wakatobi District through the Department of Marine and Fisheries (DKP).

Final Jurassic Period Formation Process

As a part of WNP, Kaledupa has a unique formation process. According to Hall (2002) and Hall (2012), based on its formation history, this island was a continental block from West Australia during the final Jurassic period (about 160 million years ago). Banda block was separated from West Australia and moved to north in 110 and 90 million years ago and then collided with Southeast Asia. During the Cenozoic era, (around 5 million years ago), there was a complex collision in eastern Indonesia (Charlton 2000; Hall and Wilson 2000), including Kaledupa Island (Milson 1999). Wilson (2008b) and Madden *et al.* (2013) state that Kaledupa formation during the Cenozoic era gives unique record regarding ancient raised coral reefs.

Figure 1. Study area (Kaledupa Island)



Wakatobi is a contingent micro with Buton Island, which was then separated as a result of a collision and post-collision event between Indonesian plates during the Jurassic era (Satyana *et al.* 2008; Satyana and Purwaningsih 2011). Satyana and Purwaningsih (2011) explain that Buton is the head of a contingent micro, while Wakatobi is the tail. When Buto collided with Mina, there was a relaxation formation of the collapse structure in the connection area between Wakatobi and Buton. However, there is no geological and geophysical data which refute the fold and thrust belt concepts provided by Davidson (1991).

Pliocene Period Formation Process

Kaledupa Island was formed through the levitation of coral reefs from Banda Sea due to a geological process (Satyana and Purwaningsih 2011). The levitation became the coastal terrace during the Pliocene Period (around 5 million years ago) (Wilson 2008a; Wilson 2008b). The next process was the development of new active coral reefs around the island (Wilson 2008b; Madden *et al.* 2013). However, this event did not stop, instead it continued to become a modern fringing reef which presented around the island during the Quarter-Pliocene era. The higher the coastal terrace, the older the rocks age. Ambewa formation is one of the examples of shallow reefs' sediment (limestone terrace) from the Final Miocene and Initial Pliocene Age, as occurred in Ambewa formation, Kaledupa Island (Wilson 2002).

Methods

The Identification of Island Morphological Characteristics

The morphological aspect is divided into land morphology (beach typology, island elevation, and land slope) and seafloor topography. Landsat 8 OLI 2016 satellite image and Worldview 2 of 2013 data were utilised for remote sensing to identify the beach typology. Furthermore, in order to know the land topography (elevation) and seafloor of Kaledupa Island, SRTM (Shuttle Radar Topography Mission), data was obtained or downloaded from this site ftp:/topex.ucsd.edu/pub/srtm30_plus/srtm30/data/. SRTM data was processed by using Global Mapper 18 and Surfer 13 software. Meanwhile, in order to obtain the island slope value, the island elevation data was processed through the utilisation of ArcMap 10.3 software.

The Identification of Island Hydro-oceanography Characteristics

The hydro-oceanography of this research consists of currents, waves, and sea level temperature which were supported by a wind condition review. These four parameters are correlated to each other. The hydro-oceanography data of this research was the dataset 2017 downloaded from the site http://marine.copernicus.eu/. The processing of currents, waves, and sea level temperatures used *Ferret version* 6.02 software. *WRPlot View* software was also used to present the image of wind, currents and waves based on the direction and speed. The benefit of using data from http://marine.copernicus.eu/ is that it can be obtained easily and free and the product is *time series*. The weakness of the use of this data is that it has a global nature, so that the next small islands can be measured directly in the field (study location) to combine the data from http://marine.copernicus.eu/.

Result and Discussion

Land Morphology

Based on the analysis result, the total width area of the island was 8,109.33 ha in 2016. Kaledupa is 10 meters above the sea level along the beach area. Hoga Island can be categorised as low land, by having height of 10 – 20 meters. The height of island in the administration area of Kaledupa Sub-district (northern Kaledupa), is 10-100 meters. Lentea and Darawa Islands are 10-40 meters above the sea level. Meanwhile, Southern Kaledupa area has height of 189 meters above the sea. Such conditions indicated that Kaledupa Island has various topography affected by the island formation process in the Pliocene era (Wilson 2008b; Madden *et al*. 2013).

The height of the Island is lower than Wangi-wangi Island. Satyana and Purwaningsih (2011) state that the biggest island in Wakatobi Islands is Wangi-wangi, which is the central ridge by having a maximum height of 270 meters above the sea level, while the other three islands, including Kaledupa almost reach 200 m. Major *et al.* (2013) explain that coral forms a hard surface layer in the coastal beach, in several areas located more than 100 m above the sea level. Each height level is claimed to have different age, in which the rocks in higher land is older than the rocks in lower land.

The various height of each terrace indicates a different levitation period (Ramos and Tsutsumi 2010). Grove *et al*. (2010) who analysed various speeds of terrace levitation, explain that a higher terrace was formed earlier compared to a lower terrace. This research did not perform geological period scale or radiometric calendar to know the age of Kaledupa Island rock age certainly. According to Major *et al.* (2013), it is better to explain the terrace morphology and coral age by identifying the major terrace, the terrace which is mostly formed, and the minor terrace which is mostly eroded into the older terrace. Wilson (2008b) and Madden *et al.* (2013) explains that when the coral reefs elevate to the sea level and become land, then the new active coral reefs system is developed around the island. The new coral reef is then levitated again becoming land.

For the detail, various heights of Northern Kaledupa and topography of Hoga Island, along with the air photos of Hoga Island and Sombano cape are presented in Figure 2a-d. The variety of the southern island, Lentea and Darawa Island is presented in Figure 3a-b.

Figure 2. Variety of northern Kaledupa Island height (a) and topography of Hoga Island (b), along with the air photo of Hoga Island (c) and Sombano cape (d)

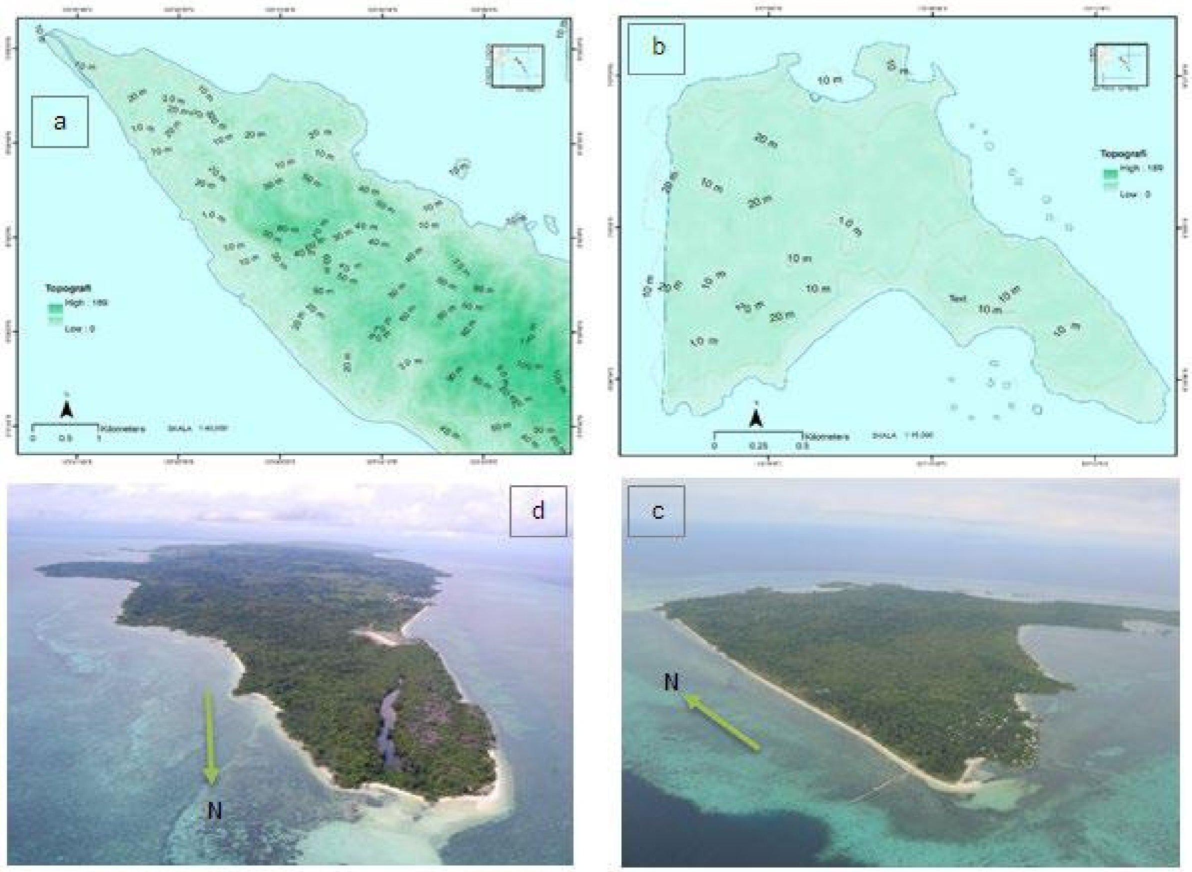
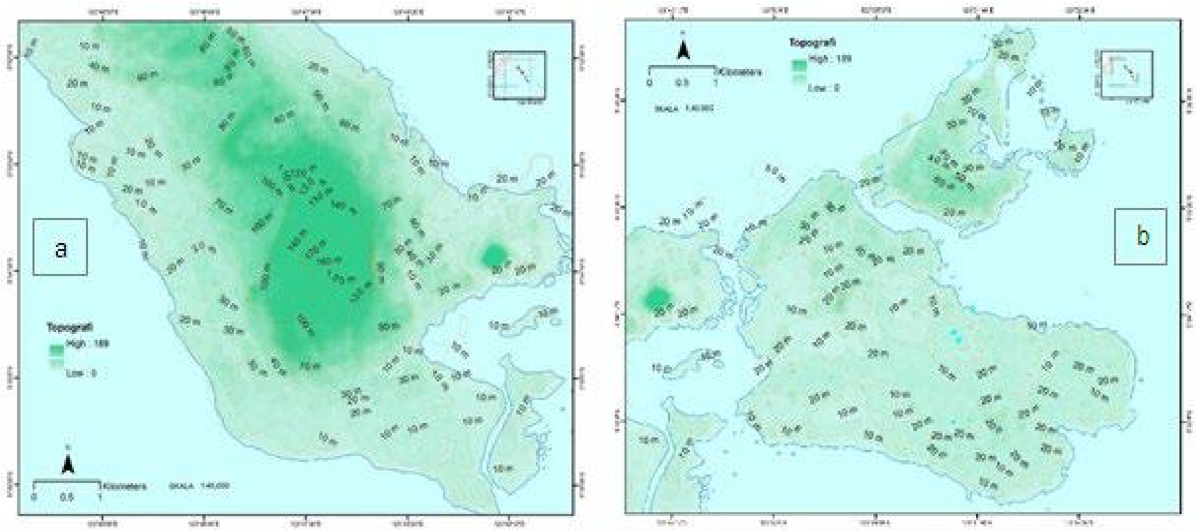
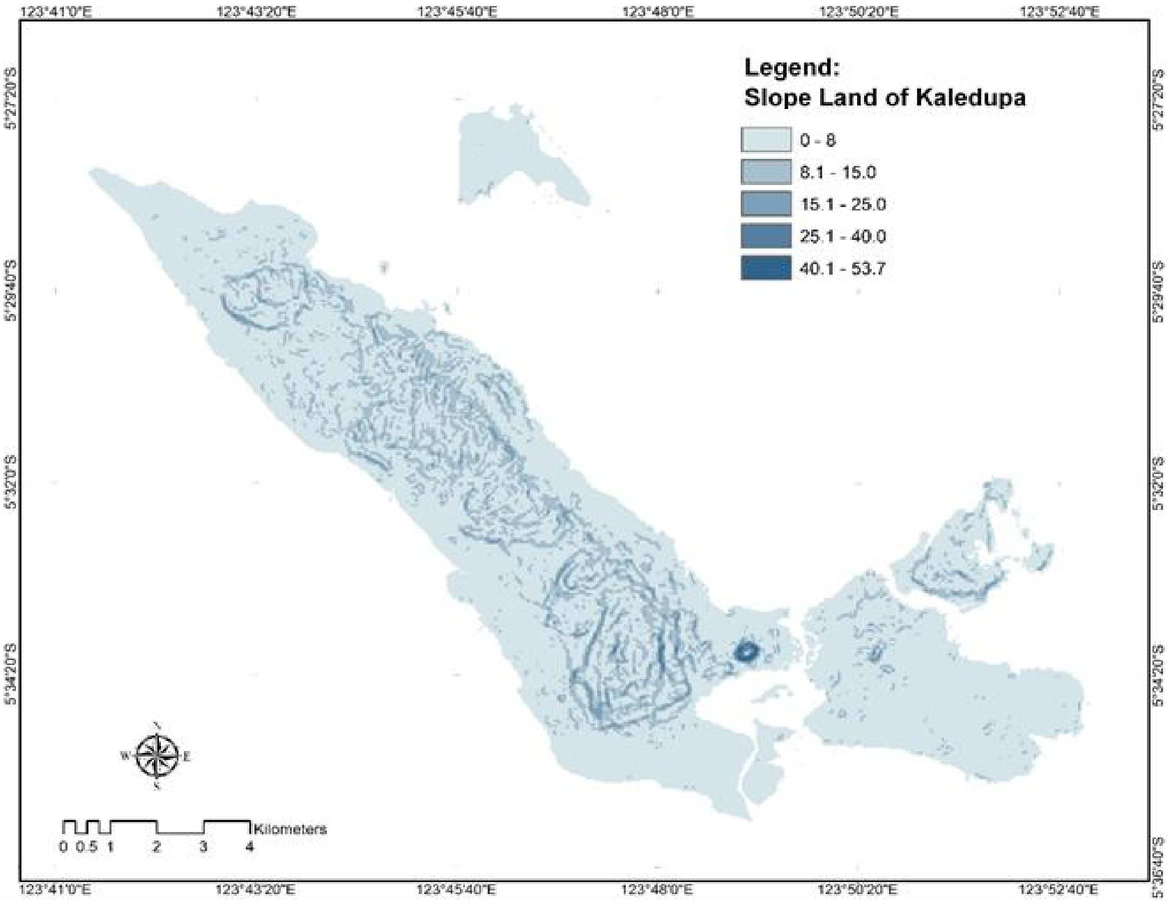


Figure 3. Height variety of Southern Island (a), Lentea and Darawa (b)



According to Figure 2c and 2d, it can be seen that the shallow waters of Hoga and Kaledupa Islands from *forehore-backshore* to *reef slope* is shallow waters' habitat. Madden *et al.* (2013) state that this area is modern coral reefs' carbonate. The carbonate sediment will become the new coastal terrace when there is another levitation. The island height data was processed further to determine the island slope value. The data analysis obtained slope of 53.7^o, which is divided into 5 slope classes (0-8^o; 8.1-15.0^o; 15.1-25.0^o; 25.1-40.0^o; and >40^o). According to the comparison between northern Kaledupa and southern Kaledupa, it is seen that southern Kaledupa has a high slope (>40^o). The slope map of Kaledupa can be seen in Figure 4.

Figure 4. Slope Map of Kaledupa Island land



The beach typology in northern Kaledupa Island, especially Higa Island and Sombano Cape (can be seen in Figure 1 and Figure 2) is sandy beach. In this island, sandy beach is structured by white sand combined with rocks. The material structuring the beach comes from the coral reefs around the island waters. The beach in this northern island is not only sandy but habituated by mangrove and other land vegetation. Meanwhile, the beach typology in southern beach is dominated by a rocky beach and a few sandy beaches (especially in Peropa). The rocky beach in this location is the beach which has a cliff, generally has the nature of having a lunge beach wall which is directly connected to the sea. The cliff beach found in southern Kaledupa Island is hard coral cliff which is not easily broken. Furthermore, there is also a vegetated beach. In the eastern Kaledupa Island (Lentea and Derawa Island), there are sandy beaches and a mangrove vegetated beach.

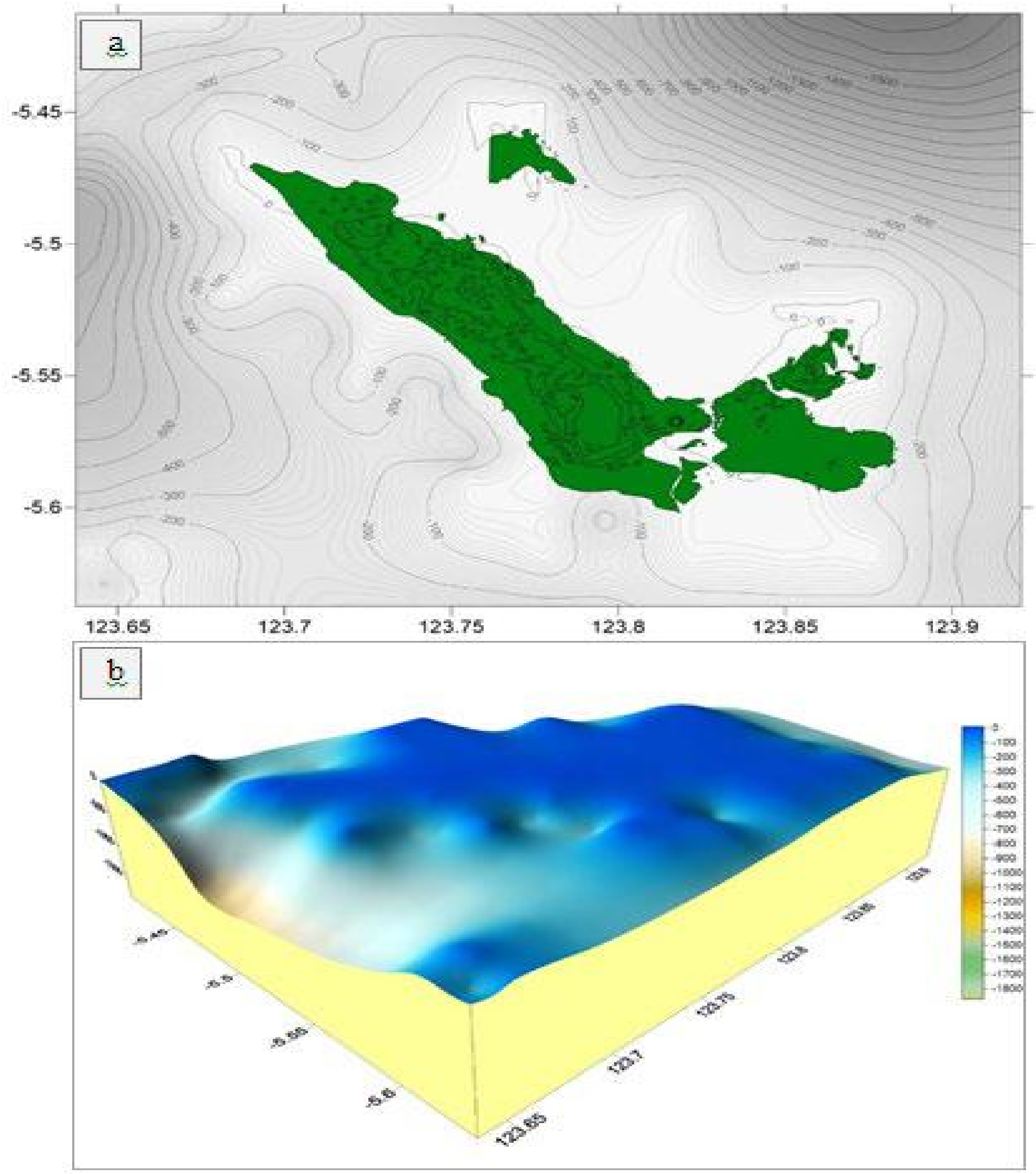
The Morphology of the Island Seafloor

The island seafloor morphology in this research is defined as topography of seafloor or often called bathymetry. The seafloor does not have even topography since it has the deepest and most shallow topography. Based on the characteristics of its different depth, the sea is divided into several zones. By utilising SRTM data and the use of *Global Mapper* 18 and *Surfer* 13 software (to present 2D and 3D bathymetry), the bathymetry value of Kaledupa Island waters is determined ranging between 0 to 1,800 meters. The depth value of the southern island which is closed to the island, land is steeper than the northern part. This can be seen that the northern land of the fringing reef is wider than the southern part. Furthermore, the southern island has a wavier seafloor relief than the northern part. The bathymetry map of Kaledupa Island is presented in Figure 5.

Based on Figure 5 related to the depth level, the bathymetry of Kaledupa Island (especially the research location) is in a littoral zone or tidal area (the depth is less than 50 m), neritic or shallow sea (50-200 m) and batial or deep sea (200-2,000 m). The air temperature and sunshine significantly affects the littoral zone, so that it is possible for the coral reefs, seagrass, and other ecosystems to need sunshine in order to develop well. The neritic zone is an area which still can be penetrated by sunshine although its intensity is smaller than the littoral zone. The organisms living in this zone include phytoplankton, zooplankton, and economic fish caught by the fisherman.

Topography has an important role both ecologically and for its physical functions. Physically, bathymetry can affect the currents and wave direction deviation. Ecologically, the relief of wavy seafloor has a good function as haven for the fish from predators. Kobara and Heyman (2008) state that the grouper spawning aggregation location is mostly found in the depth range between 25-45 m and less than 50 m. The depth has a correlation with the distribution pattern of fish (Blaber *et al.* 1994). This indicates that the relief of the wavy seafloor (cape) and areas, having a depth between 25-45m, needs to become the parameter in designing natural resources conservation and small island management. Erisman *et al.* (2017) ensure that fish spawning aggregation location is important to be protected for the continuity of fish breeding and increase of fish biomass. Thus, the use of fish remains sustainable.

Figure 5. The Bathymetry of Kaledupa Island waters; 2 dimension image (a) and 3 dimension image (b)



Hydro-Oceanography of the Island

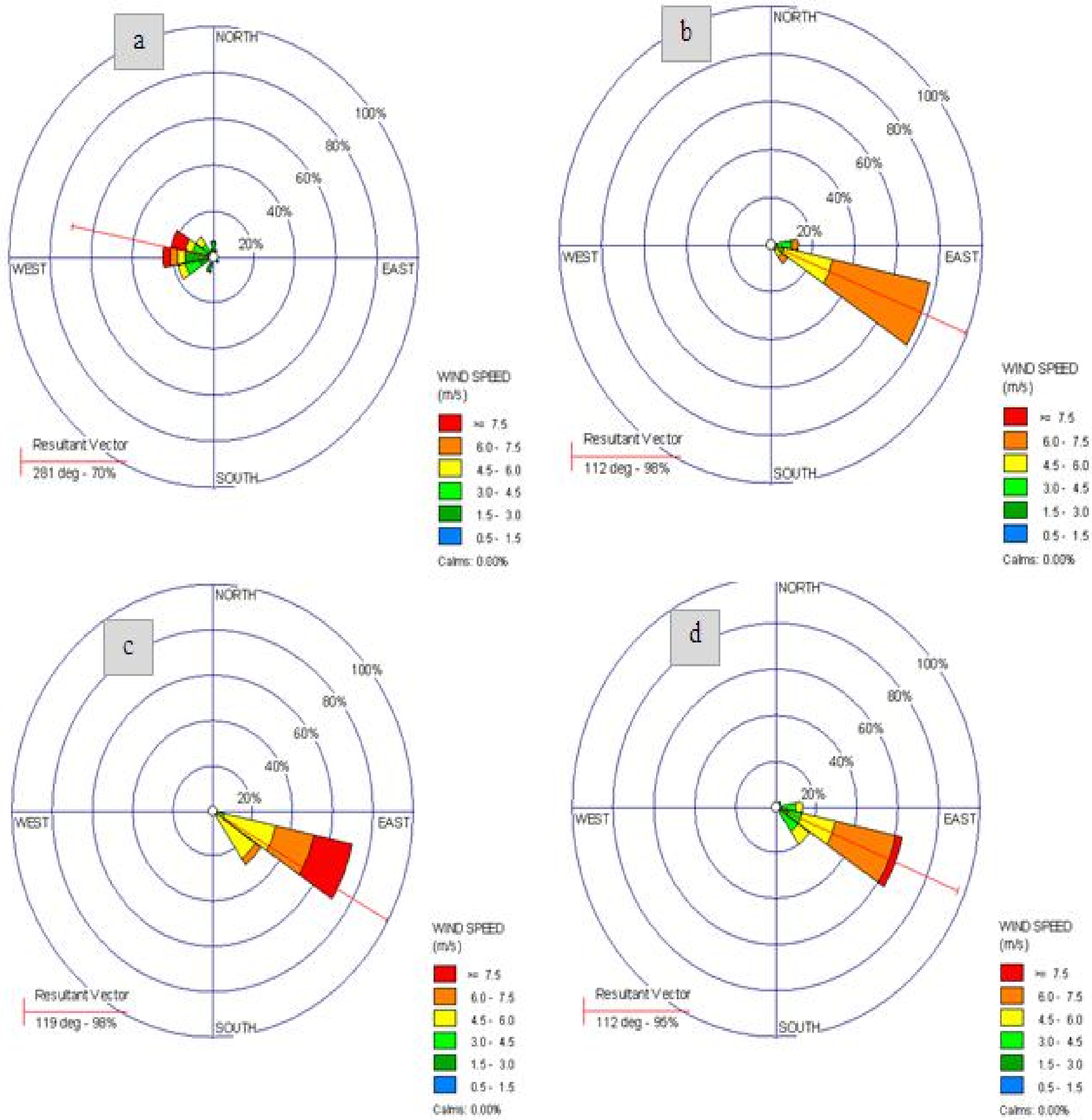
The hydro-oceanography of Kaledupa Island cannot be separated from Wakatobi Islands in terms of condtions. Therefore, this review explains hydro-oceanography along with Kaledupa and Wakatobi Islands in general. The hydro-oceanography of the review location is affected by the geographical position and the monsoons, condition. Geographically, the area waters are boarded with the Banda Sea in the north and east, and boarded with the Flores Sea in the south. Monsoons ss the wind pattern, blow periodically (3 months at least) and the periods contradict wind patterns and change the direction every half a year (Triadmodjo 1999; Daruwedho *et al.* 2016). Monsoons are divided into two, those are west and east. West monsoons or west season occurs in June, July and August. In addition, there is a transition period which is changes from west monsoons to east monsoons and vice versa. The transition I flows between March to May, while transition 2 is from September to November.

Sea Breeze

Indonesia's wind pattern is commonly affected by monsoons occurring due to the sun position's change in one year period. Such patterns also happen in Wakatobi Island. Wind is one of the factors causing currents and waves. Based on the characteristics' identification result using WRPlot, there were various wind directions in Wakatobi (especially in Kaledupa Island) during 2017, but it was dominantly from east/southeast and west. During the west season (December-February), the wind blew from the west. In February, the wind dominantly blew from the west with the average angle of 281^o. The highest wind speed recorded was more than 7.5 m/second and was at the percentage of 3% from 70%, while the lowest wind speed was 0.5-1.5 m/second blowing from the southeast and southwest. During the transition I especially in May, the wind dominantly blew from the east/southeast, with the average angle of 112^o. The highest wind speed (6.0-7.5 m/second) was at the percentage of around 48% from 98%. The lowest wind speed was at the range of 3.0-4.5 m/second blowing from the southeast and east.

The wind during east season, especially in July, predominantly blew from east southeast with the average angle of 119$^{o.}$ The highest wind speed value in this month was more than 7.5 m/second and was at the percentage of about 18% from 98%, while the lowest wind speed was 3.0-4.5 m/second. Furthermore, the wind in the transition 2 period, especially in September blew predominantly from the east southeast with the angle of 112^o. The highest wind speed value (more than 7.5m/second) was at the percentage of around 3% from 95%. The smallest wind speed was at the range of 0.5-1.5 m/second. The wind rise characteristics in Kaledupa Island in each season in 2017 is presented in Figure 6.

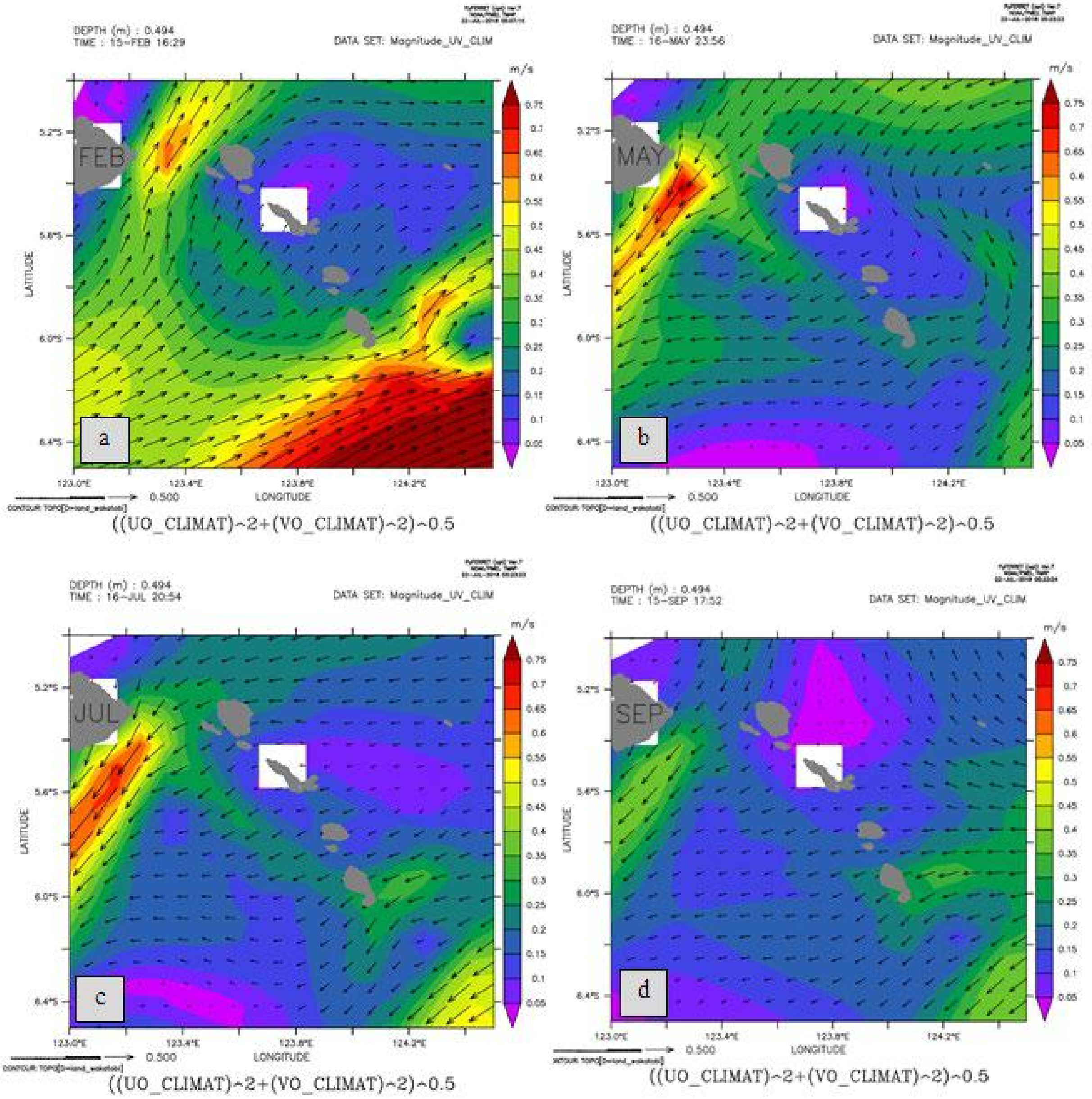
Figure 6. The visualisation of wind rise characteristics in Kaledupa Island and Wakatobi in each season in 2017. February (a), May (b), July (c) and September (d)



Sea Level Currents

The sea level currents are the movement of water mass caused by the wind blowing at sea level in the depth of less than 200 m, moving from one place with high air pressure to another place with low air pressure (Groos 1990; Daruwedho *et al.* 2016). The spatial visualisation of currents' speed in the research location, as the representative of each season in 2017, can be seen in Figure 7.

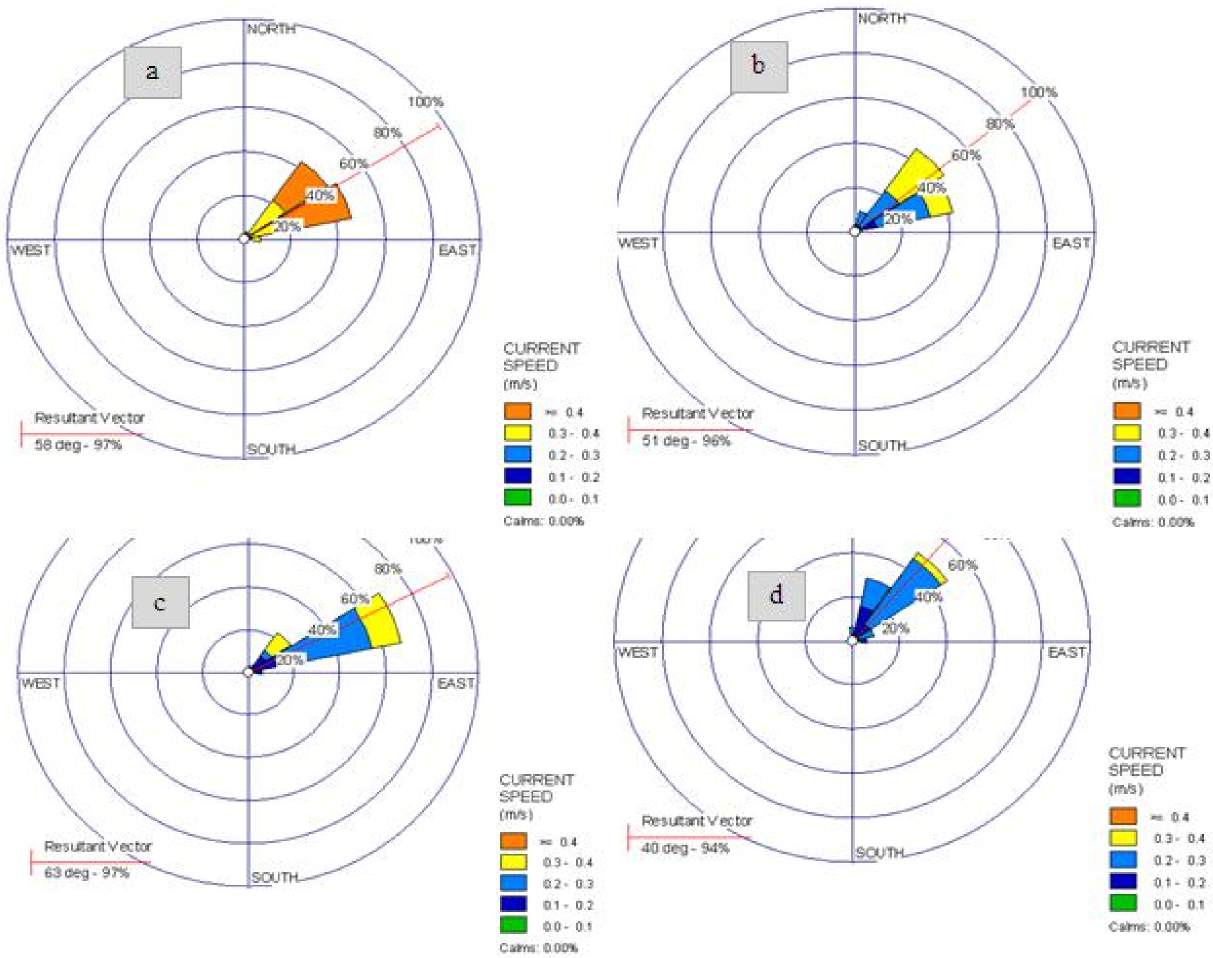
Figure 7. The spatial distribution of currents speed of Kaledupa Island and Wakatobi of each season representative in 2017. February (a), May (b), July (c) and September (d)



The currents' speed during the west season 2017 (December-February) was at the range of 0.05-0.75 m/second. The highest currents' speed (0.75/second) occurred in the northwest of Wangi-wangi Island (around 5.2º SL and 123.4º EL). Kaledupa waters' current in February had a speed of 0.05-0.15 m/second. During the transition season I (March-May), the highest currents' speed in May was at the range of 0.05-0.75 m/second. During the east season (June-August), the highest wind speed was in July (reaching 0.7 m/second). In Kaledupa waters, the currents' speed reached 0.2 m/second. Meanwhile, in the transition 2 period (September-

November) the highest currents' speed in Wakatobi waters occurred in September (reaching 0.5 m/second). In Kaledupa Island waters, the currents' speed reached 0.1 m/second.
The visualisation of current rise characteristics of the sea level I Kaledupa Islands of the representative in each season in 2017, is presented in Figure 8. The currents of Wakatobi sea level during the west season (especially in February) predominantly spread to the northeast with the average angle of 58°.

Figure 8. The visualisation of current rise characteristics of Kaledupa Island and Wakatobi sea level in each season representative in 2017. February (a), May (b), July (c) and October (d)



The highest currents' speed value was more than 0.4 m/second, which was at the percentage of 32% from 97%. The lowest currents' speed was 0.2-0.3 m/second which spread to the northeast and east. During the transition I period (especially May), the sea level currents predominantly spread to the northeast with an angle of 51°. The highest currents' speed is at the range of 0.3 – 0.4 m/second, which was at the range of 23% from 96%; the lowest currents' speed in this month was 0.0-0.1 m/second. During the east season (especially in

July), the sea level currents predominantly spread to the northwest with an angle of 63°. The highest currents' speed in this month was 0.3-0.4 m/second, which was at the percentage of 13% from 97%. Meanwhile, the lowest currents' speed was 0.1-0.2 m/second. During the transition 2 period (especially in September), the currents spread to the northwest with an angle of 40°. The highest currents' speed was 0.3-0.4 m/second, having a percentage of around 7% from 94%. The lowest currents' speed was at the range of 0.0-0.1 m/second.

Waves

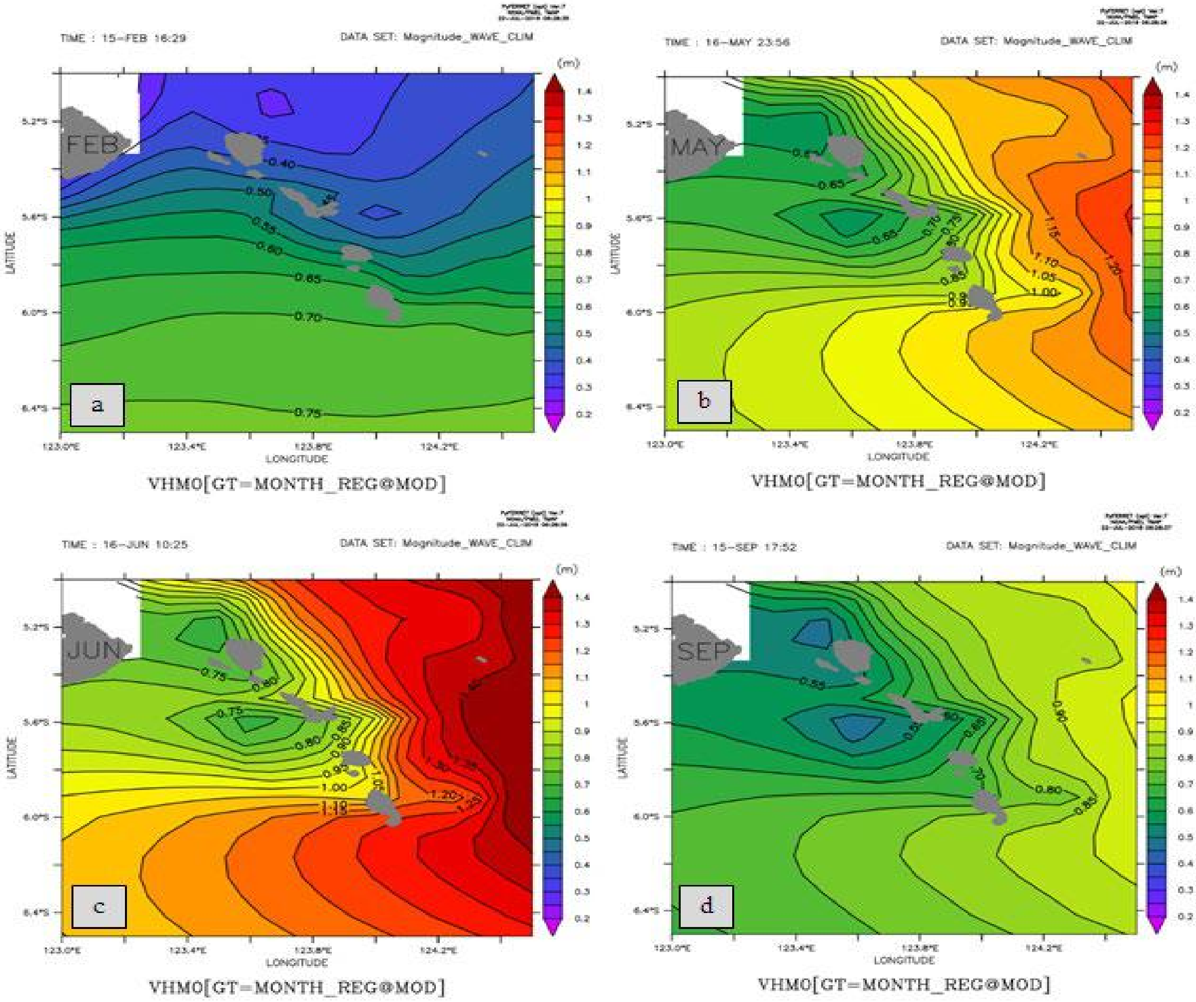
The waves in the waters of Kaledupa Island during 2017 was at the range of 0.2 to 1.4 m. During the west season (December-February), the biggest wave occurred in February which was 0.80 m. especially in Kaledupa Island, the wave height was at the range of 0.40 – 0.50 m. during the transition I period (March-May); the highest wave occurred in May (1.25 m). The wave in the waters of Kaledupa Island was at the range of 0.65-0.80 m. Spatial visualisation of the wave height from each season representative in 2017 can be seen in Figure 9. The wave during the east season (June-August) was the highest in June which was 1.4 m. The wave in the waters of Kaledupa Island in this month was at the range of 0.70-0.80 m. During the transition 2 period (September – November), the highest wave in the waters of Wakatobi Island occurred in September (1 m). The wave in the waters of Kaledupa waters reached 0.55-0.65 m.

The visualisation of wave rose characteristics in the waters of Kaledupa Islands of each season representative in 2017 is presented in Figure 10. The wave of the Wakatobi Sea during the west season (especially in February) predominantly moved from west-southwest with an angle of 235°. The highest wave value was above 1.5 m, which was about 3% from 79%. The lowest wave was between 0.3-0.5 m. in the transition I season (especially May); the wave moved from the east/southeast with an angle of 112°. The highest wave was at the range of 1.3-1.5 m, which was at the percentage of 8% from 100%. The lowest wave was in May at 0.3-0.5 m.; the sea wave during the east season (especially in June) predominantly moved from east/southeast with an angle of 112°. The highest wave value was above 1.5 m, at the percentage of about 21% from 100%. The lowest wave was between 0.5-0.8 m. during the transition 2 season (especially in September); the wave moved from east/southeast with an angle of 120°. The highest wave was above 1.5 m, which was at the percentage of 3% from 81%. The lowest wave in September was 0.5-0.8 m.

Sea Level Temperature

One of the most important factors for the marine organism is the sea level temperature, because it is needed in metabolism and breeding activities of the organisms in the sea. The optimal value of water temperature for the corals' growth is at the range of 26-28°C, while the general waters' temperature was at the range of 18-36ºC. If the temperature exceeds this normal threshold, it will cause coral whitening. Based on the analysis result, the temperature of Kaledupa Island waters is at the range of 27-30.5ºC.

Figure 9. Partial visualisation of the sea wave of Kaledupa Island and Wakatobi waters from each season representative in 2017. February (a), May (b), June (c), and September (d)



The highest sea level temperature of Kaledupa Island in 2017 occurred in April to May (around 30.5ºC) and in November (around 30.5ºC). Meanwhile, the lowest temperature occurred between August – September which was around 27ºC. This indicates that the temperature of Wakatobi sea level (especially Kaledupa Island) remains at the range of normal threshold and supports the growth of the coastal ecosystem. The distribution of sea level temperature in Wakatobi Islands in 2017 can be seen in Figure 11.

Figure 10. The visualisation of sea wave rose in Kaledupa Island and Wakatobi from each season representative in 2017. February (a), May (b), June (c), and September (d)

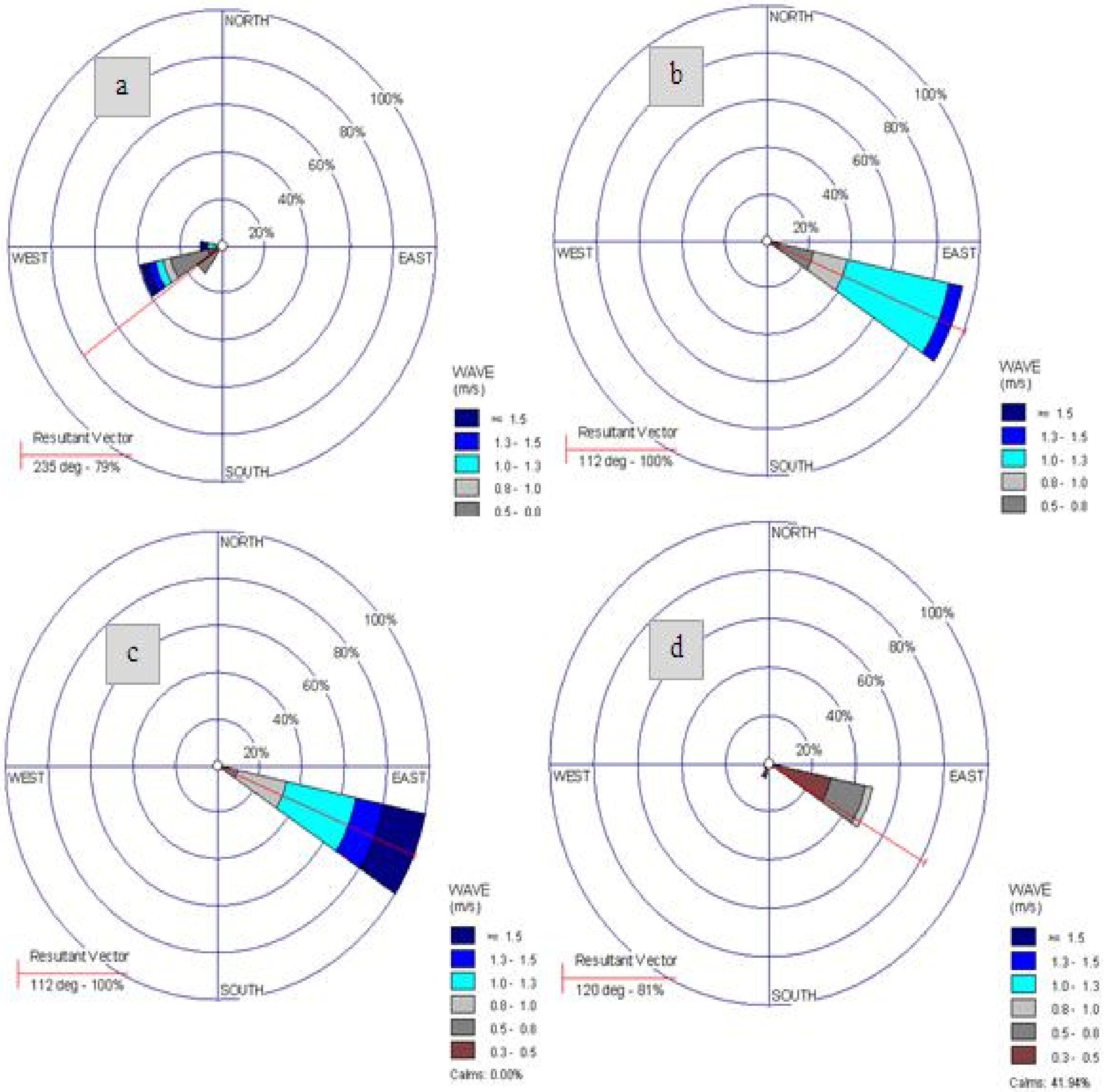
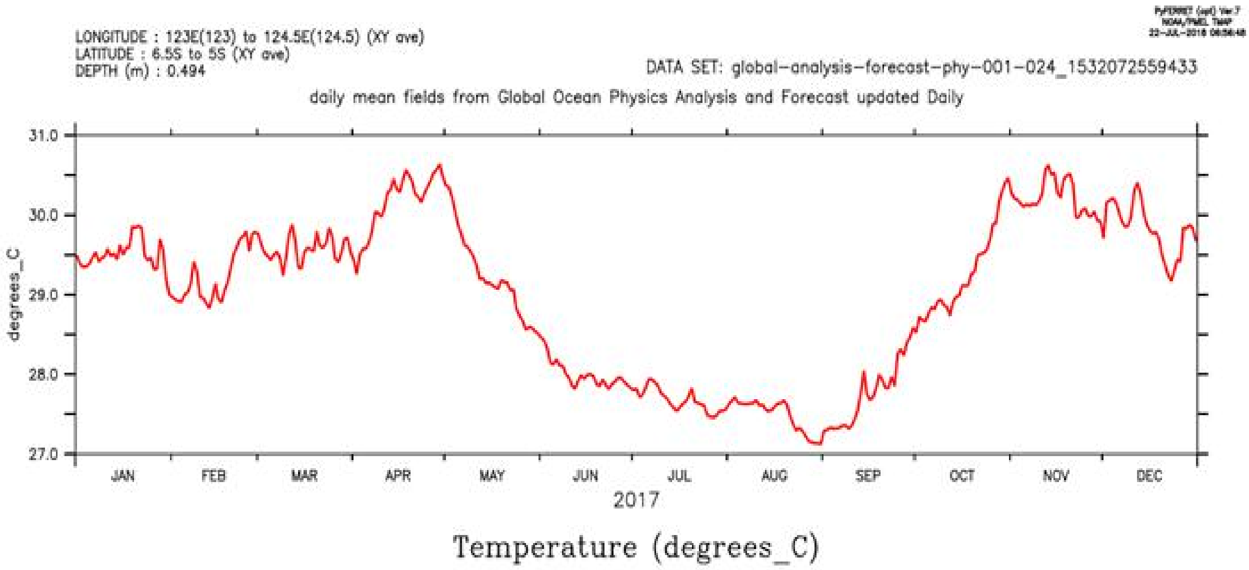


Figure 11. The distribution of sea level of Kaledupa Island in 2017



The Correlation between Hydro-oceanography and Kaledupa Island

Small islands have high environmental susceptibility (Bruguglio 2003); they are easily affected by the sea wave and currents. The effect which mostly occurs is beach erosion causing the loss of land (USCCSP 2009). The higher the wave and the currents, the higher the island's' susceptibility. DKP (2008) and Tahir (2010) state that a sea level with the height of more than 2 m will cause a high susceptibility level in the small islands. Based on the result of hydro-oceanography analysis, the wave and currents' condition in Kaledupa Island waters during the year was consecutively at a range of 0.5-0/85 m and 0.10-0.15 m.; if this wave and currents' condition is correlated with the island's susceptibility level, then it can be considered that the wave and currents is at very low to low susceptibility class.

The islands susceptibility can be minimised through the presence of a coastal ecosystem (coral reefs, seagrass and mangrove). The role of coral reefs' ecosystem is to muffle the wave energy which is headed to the beach (Tahir 2010). Kench *et al.* (2006) state that the change of the wave and currents' height towards the beach is proportionate with the length of coral reefs near the beach. Mangrove ecosystems have the ability to catch sediment, protect the beach from windstorms, prevent coastal floods (Mahmood *et al.* 2005), as well as slow down beach erosion (Vermaat and Thampanya 2006). The seagrass ecosystem of the beach also has a role to catch the sediment so that it can protect the coastline from waves (Tahir 2010). Therefore, in order to minimise the susceptibility of Kaledupa Island, these three ecosystems must be protected.

The Correlation between Hydro-Oceanography and Coastal Ecosystems of Kaledupa Island

The currents, waves and temperature of sea level have a tight relationship with the coral reefs, seagrass and mangroves. A strong current has an important role for coral growth, particularly to supply microorganisms food and oxygen as well as protecting the coral from sediment pile. The range of optimal current for coral reefs is 0.05-0.08 m/second (Thovyan *et al.* 2017). Strong waves also support the growth of coral reefs since they bring the sea water which contains much oxygen and prevents the sediment to stick on the colony. The sea level temperature affects the coral reefs as well. The ideal temperature for coral growth is at the range of 27.5-29ºC (Thovyan *et al.* 2017); as stated by Thamrin (2006) that hermatipic coral grows and develops well at the temperature range between 25-29ºC. The minimum and maximum temperature that can be tolerated by the coral reefs is 16ºC and 33.5ºC.

The maximum currents' condition throughout the year (0.10-0.15 m/second) and maximum wave (0.5-0.085 m) in Kaledupa Island is relatively strong, so that it can support the growth and development of coral reefs. The condition of sea level temperature which is at the range of 27.2ºC-30.5ºC was also still at the range of the normal threshold value for the coral reefs to live. This can be seen that along the islands' coastal (both from the north-south or the east-west of the island), the coral reef grows well in the waters of Kaledupa Island.

The currents' condition affect the seagrass density. The currents' speed of 0.03-0.14 m/second can provide life opportunities for the seagrass but with solid density; the currents' speed of 0.09-0.10 m/second provide life opportunity for the seagrass with medium density, while the currents speed of 0.02-0.04 m/second makes the seagrass to have sparse density (Kusumaatmaja *et al.* 2016). Meanwhile, Rahman *et al.* (2015) states that the currents' speed of 0.5 m/second is the optimum condition for the seagrass to grow well. Meanwhile, the wave which is too weak can disturb the presence of seagrass, since it can cause organic material accumulation, while waves which are too strong can damage the seagrass due to excessive sediment transportation, so that it enables the tillers to grow or cover the seagrass. The sea level temperature has an important role in the physiology process such as photosynthesis, respiration speed, growth and reproduction. The range of optimal temperature for the seagrass to grow well is 28-30ºC, while for the photosynthesis activity, seagrass needs an optimal temperature at the range of 25-35ºC.

Maximum currents' speed throughout the year was at the range of 0.1-0.15 m/second, while the maximum wave height was at the range of 0.5-0.085 m in Kaledupa Island; this is a good parameter for the seagrass to grow and develop. The temperature of sea level throughout the year was at the range of 27.2ºC-30.5ºC, which is still at the range of optimal threshold for the seagrass to perform photosynthesis. This can be proven by the presence of seagrass in the waters of Kaledupa Island, which is really good.

Currents and waves affect the mangrove susceptibility. The speed of currents below 0.2 m/second is categorised as a low susceptibility class, the range of 0.2-0.4 m/second is categorised as a medium susceptibility class, while currents speed above 0.4 m/second means a high susceptibility (Vitasari 2015). Meanwhile the wave height of less than 1 m will give low mangrove susceptibility, at the range of 1-1.15 m is at medium susceptibility, while a wave above 2.5 m is at high susceptibility (Vitasari 2015). The water temperature significantly affects the mangrove, particularly the activity of decomposition of mangrove leaves. Hutchings and Saenger (1987) state that *Avicennia marina* produces new leaves at a temperature of 18-20ºC; *Rhizopora spp*. and *Ceriops spp.* at the temperature of 26-28ºC; while *Bruguiera spp*. at the temperature of 27ºC.

Maximum currents' speed throughout the year is at the range of 0.1-0.15 m/second and the maximum wave height was at the range of 0.5-0.85 m in Kaledupa Island, which is the value giving low susceptibility to the mangrove. Meanwhile, the sea level temperature throughout the year at the range of 27.2ºC-30.5ºC, is the optimal range for the mangrove to grow. This can be proven by the good presence of mangrove on the coast of Kaledupa Island, especially *Avicennia marina*, *Rhizopora spp*., *Ceriops spp.,* dan *Bruguiera spp*.

Conclusion

Kaledupa Island is a small island formed by coral reefs levitated to sea level due to geological processes. The levitation became the coastal terrace during the Pliocene era (around 5 million years ago). The island morphology formed currently is the result of island formation process which occurred for one hundred years. Therefore, the island morphology is an interesting aspect to be studied as the parameters of small island management input. Based on the result of this research, the beach typology seen in the north of the island consists of sandy and vegetated (mangrove) beach, the southern beach consists of rocky and sandy beach, the elevation of Kaledupa island is various, from 0 meter in beach area to 189 meter at the top of the island. The highest area is the oldest coral reefs' terrace, while the lowest area is the youngest coral reefs' area. The slope of the land is at the range of 0-53.7º; the depth value of the sea is at the range of -0.1 to -1,800. These parameters can give the susceptibility value for the island ranging from the very low to low.

Meanwhile, the maximum hydro-oceanography parameter throughout the year is seen based on the current speed which reaches 0.2 m/second in July, the highest wave occurred in June at the range of 0.70-0.80 m; the highest sea level temperature (around 30.5ºC) occurred between

April to May and November. This condition is the threshold value that can give low susceptibility.

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