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OFFSHORE FLOATING MARINE FISH CAGE AQUACULTURE DEVELOPMENT PLANNING EVALUATION BASED ON HYDRO-OCEANOGRAPHY CONDITIONS IN SABANG BAY, WEH ISLAND

EVALUASI PERENCANAAN PENGEMBANGAN BUDIDAYA KARAMBA JARING APUNG DI KAWASAN LEPAS PANTAI BERDASARKAN KONDISI HIDRO-OSEANOGRAFI DI TELUK SABANG, PULAU WEH

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ABSTRACT

Sabang coastal bay becomes the area of significance where the development centered in the semi-enclosed area. Sabang Bay is well-known as the center of marine economy (Aquaculture, Harbor, and marine tourism). Recently, there is a planning initiated by Ministry of Marine Affairs and Fisheries (MMAF) to install the *floating fish cage aquaculture* (KJA) in the offshore area of Sabang Bay which the planning becomes a controversy between local people, local government, and researchers as well. This study aims to evaluate and discuss the impacts that will be happened if KJA is applied. Field surveys on hydro-oceanography aspects were done measuring currents, tides, waves, winds, bathymetry, water quality, as well as tourism condition. Based on those hydro-oceanography conditions, Sabang Bay categorized into calm water area where the sea current is weak (ranging from 0-0.12 m/s), whilst the high values of pH, salinity, and temperature are identified within the bay during low tidal condition. If KJA is installed within the bay, automatically it will pollute the water due to the accumulation of remaining fish feeder wastes. Moreover, within the bay, there are several attractive marine tourisms such as diving sites, the conservation area of *Sophie Rickmers* shipwreck site, and hot bubble (*fumaroles hydrothermal vent*). The presence of KJA will possibly disrupt marine tourism activities so that the implementation of KJA needs to be considered the impacts before installation.

Keywords: floating marine fish cage, Sabang Bay, hydro-oceanography conditions

ABSTRAK

Pesisir Teluk Sabang menjadi kawasan penting yang pengembangannya berpusat di kawasan semi-tertutup. Teluk Sabang terkenal sebagai pusat ekonomi kelautan (budidaya, pelabuhan, dan wisata bahari). Akhir-akhir ini, terdapat beberapa perencanaan yang diinisiasi oleh Kementerian Kelautan dan Perikanan (KKP) untuk mengembangkan budidaya Karamba Jaring Apung (KJA) di kawasan lepas pantai Teluk Sabang, yang mana perencanaan jni menjadi kontroversi antara masyarakat lokal, pemerintah daerah, dan peneliti juga. Penelitian ini bertujuan untuk melakukan evaluasi dan mendiskusikan dampak yang akan terjadi jika budidaya KJA diterapkan. Survei lapangan pada aspek hidro-oseanografi dilakukan dengan mengukur arus, pasang surut, gelombang, angin, batimetri, kualitas air, serta kondisi pariwisata. Berdasarkan kondisi hidro-oseanografi tersebut, Teluk Sabang dikategorikan menjadi wilayah perairan yang tenang dengan arus laut yang lemah (berkisar antara 0-0,12 m/dt), sedangkan nilai pH, salinitas dan suhu tinggi yang diukur di dalam teluk pada kondisi surut terendah. KJA yang dipasang di dalam teluk, secara otomatis akan memberikan dampak pencemaran perairan yang disebabkan oleh proses akumulasi sisa-sisa pakan ikan. Wisata bahari yang ada di dalam teluk terdapat beberapa atraksi yang menarik seperti daerah penyelaman, daerah konservasi, daerah kapal Sophie Rickmers karam dan gelembung panas (lubang uap fumaroles hydrothermal). Keberadaan KJA kemungkinan akan mengganggu kegiatan wisata bahari, sehingga penerapan KJA perlu dipertimbangkan dampaknya sebelum melakukan pemasangan.

Kata kunci: *karamba jaring apung, Teluk Sabang, kondisi hidro-oseanografi*

I. INTRODUCTION

Indonesia archipelago consists of 2/3 of seas that becomes a good opportunity for aquaculture development (mariculture) (Nurdjana, 2006; Szuster and Albasri, 2010; Rückert *et al*., 2008). These great potentials, if it is served optimally, it can push the fisheries production enhancement (Neori *et al*., 2000; Watson *et al*., 2015). Indonesian fishery products that are currently in high demand in the international market have even become a prima donna of exports to a number of countries (Anderson and Fong, 1997; Unnevehr, 2008). Therefore, the government through the Ministry of Maritime Affairs and Fisheries (KKP) continues to strive to develop a mariculture industry to occupy the export demand. One of the solutions is initiating the application of modern technology in the form of *Offshore Floating Fish Cage Aquaculture* (KJA).

KJA offshore is a strategic KKP program that aims to enhance fishery production using aquaculture method, mainly for seabass (*lates calcalifer*) (Ondara *et al*., 2017). This program is adapted from Norwegian aquaculture technology that believes to be able to boost marine fish production significantly (Atmojo and Ariastita, 2018). This is in accordance with president instruction (in press) Number 7, 2016 regarding the acceleration of *National Fisheries Industry Development* (Muawanah *et al*., 2018). One of the areas where will be installed offshore KJA is Weh Island, specifically within Sabang Bay.

Sabang Bay is the most important area in Weh Island that becomes the area of significant serving a lot of marine activities such as harbor, tourism, aquaculture, fishery *etc.* (Rani et al., 2017). This water area provides fish stock due to its great biomass (Yulianto and Wiryawan, 2017). Therefore, KKP initiates KJA offshore to enhance that fish stock value (Ondara *et al*., 2017). During KJA implementation in Sabang bay, there are a lot of complaints stated by the local government, researcher, and local people that this one of mariculture method will exacerbate the environmental condition by disrupting conservation area, marine tourism activity, and generating pollution as well.

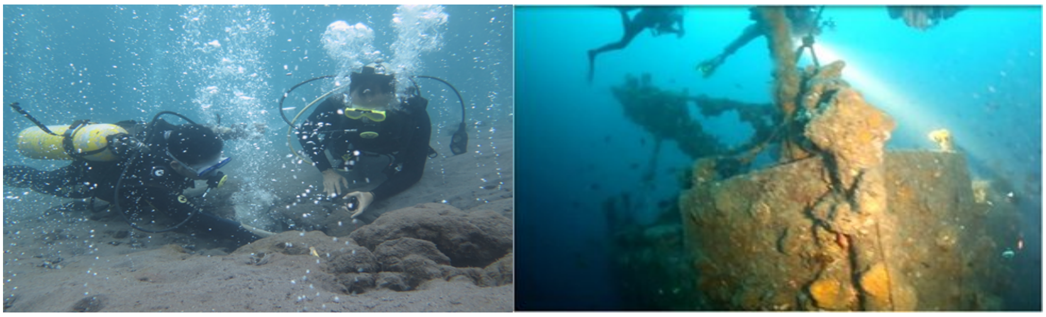
As semi-enclosed water area, Sabang coastal bay condition depends on the hydrodynamic pattern that is slightly weak for several conditions (Irham *et al*., 2018), for example, during the neap tidal condition in which the tidal range is smaller results in weaker tidal current speed (Setiawan *et al*., 2018). Those conditions will induce the accumulation of remaining fish feeder wastes sourcing form KJA. If ongoing, it can enhance the nutrient enrichment and blooming tendency as well (Marimoto *et al*., 2017). Moreover, besides its environmental impacts, KJA may decline the attractiveness of Sabang bay as one of the main destinations in Weh Island. Due to the issues above, we want to evaluate the KJA planning in Sabang bay according to its hydrodynamic conditions and analyze the impact that will be happened if it is implemented.

II. MATERIAL AND METHODS

2.1. Study Site and Observations Stations

This study focused on Sabang Bay where KJA will be installed. Sabang bay is bordered by several villages such as Cot Pengelu, Lam Nibong, Cot Sapang, Cot Pawang, Cot Gua Semantang, and Pria Laot. Around Pria Laot waters there are several attractions of merine tourism such as *Sophie Rickmers* shipwreck site, hot bubble (*Fumaroles Hydrothermal Vent*) (Figure 1).

Field measurement station of current and wave data located in the middle within the bay that *Acoustic Doppler Current Profiler* (ADCP) was installed in the position of *Sophie Rickmers* shipwreck site (Figure 2) for 29 days (started from March 16th, 2017 until April 15th, 2017).



(a) (b)

Figure 1. Hot bubble (a) and (b) *Sophie Rickmers* shipwreck.

The obtained data were then sorted using *Surge software* to filter the bias data. The ocean current data are provided in the form of layer data, we only used the uppermost layer near the surface adjusted to the model developed. So that, it can be well-compared to evaluate the simulation result. While, the wave data were extracted using *Storm software* to obtain the significant wave height and period (Dietrich *et al.*, 2011).

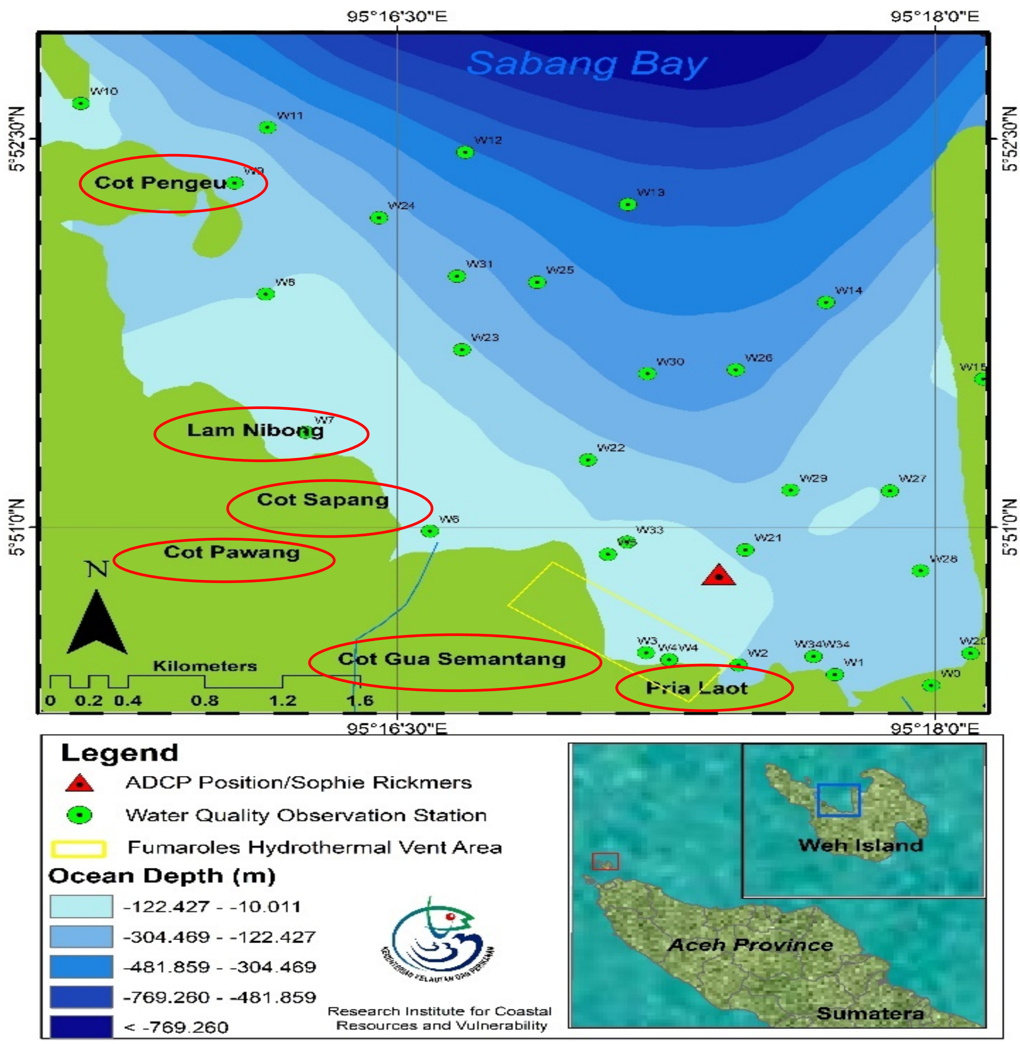


Figure 2. Research location map.

While, water quality data (pH, salinity and temperature) were surveyed on March 17th, 2017 using *TOA DKK Water Quality Checker Multi-Parameter* simultaneously. The sampling point covers 34 observation stations (Figure 2). Sampling was done during the displacement toward low tidal condition (Figure 3). We used *NAOtide software* to produce tidal forecast data (Matsumoto *et al*., 2000).

2.2. Flow Model Simulation

The simulation of tidal current uses flow model flexible mesh in the form of two-dimensional hydrodynamic model based on continuity and momentum equations which are spatially discretized by *Cell-Centered Finite Volume* method (Zhao *et al*., 1994). The simulation applied for the 1st transitional monsoon adjusted with the observation data. This simulation was generated from a flexible mesh, bathymetry, and tidal prediction bordered by four boundary conditions.

The tidal forecast was employed as the model input which is obtained from Ergtide software execution (Masoud *et al*., 2012). The model set-up is shown in Table 1. The result of the model will be depicted as a tidal current pattern for four extreme tidal conditions. These results will be validated by observation data employing Root Mean Squared Error (RMSE) formula (Spaulding and Mendelsohn, 1999) as follow:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y - yi)^2} \quad \ldots\ldots\ldots\ldots\ (1)$$

Information: n = Total data, y = model result, yi = observation result.

Table 1. Flow model simulation set-up.

Parameters	Implemented within simulation
Time of simulation	Number of time step = 100 Time step interval = 600 sec Simulation start date = 16/03/2017 19:00 Simulation end date = 31/03/2017 19:00
Mesh boundary	SRTM bathymetry data combined with field measurement
Flood and dry	Drying depth = 0.005 m Flooding depth = 0.05 m Wetting depth = 0.1 m
Boundary condition	Type = Specified level Format = Varying in time, constant along boundary Time Series = Tidal forecast on coordinates below: 1. Longitude: 95,299 E, Latitude: 5,934 N 2. Longitude: 95,400 E, Latitude: 5,836 N 3. Longitude: 95,299 E, Latitude: 5,739 N 4. Longitude: 95,199 E, Latitude: 5,836 N

III. RESULTS AND DISCUSSION

3.1. Oceanographic Conditions of Sabang Bay

Significant wave height (Hs) ranged from 0.2-1 m with the wave period (Ts) ranged from 0-20 seconds (Figure 3). Hs value is unstable during the measurement time that is maximum reaching 1 meters during March 22nd -24th 2017. This tendency is also identified during March 28th-30th 2017 with a lower wave height ranging from 0.2-0.8 m. The large-amplitude of wave propagates from the Andaman Sea that is induced by the Indian Ocean internal solitary wave generation (Vlasenko and Alpers, 2005). When the wave propagation reached shallow waters (closer to Weh Island), the generation of internal wave is induced by the interaction of baroclinic tides with shallow underwater features that wave-topography interaction takes place resulting in the semicircular small-scale wave pattern in the

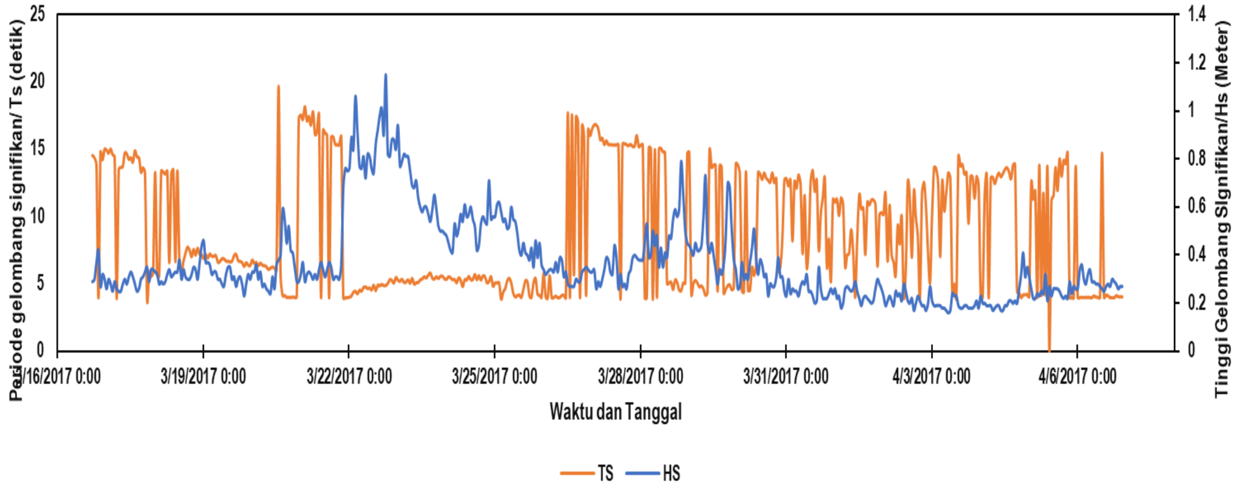


Figure 3. Significant wave height and period in Sabang Bay.

shallower area (Holloway and Merrifield, 1999; Niwa and Hibiya, 2001; Cummins *et al.*, 2001). It is clear why the wave characteristics in Sabang bay are weaker within the bay due to shallow topography and wave deformation induced by semi-enclosed area. Tidal type in Sabang Bay is mixed-tide prevailing semidiurnal which for 24 hours the waters tend to occur 2 phases of flood and ebb tides. Tidal data are also used to validate flow model simulated by comparing two tidal data provenanced from the model result and field measurement obtaining RMSE 11.98 %. Figure 4 shows that the surface elevation between those two data has the same phase, however, the difference is observed during the neap tidal condition in which the phase delay is identified. According to Dias *et al.* (2000) during neap tide, the phase distribution of M2 constituent is altered by the channels geometry and the bathymetry that induces phase delay during this condition.

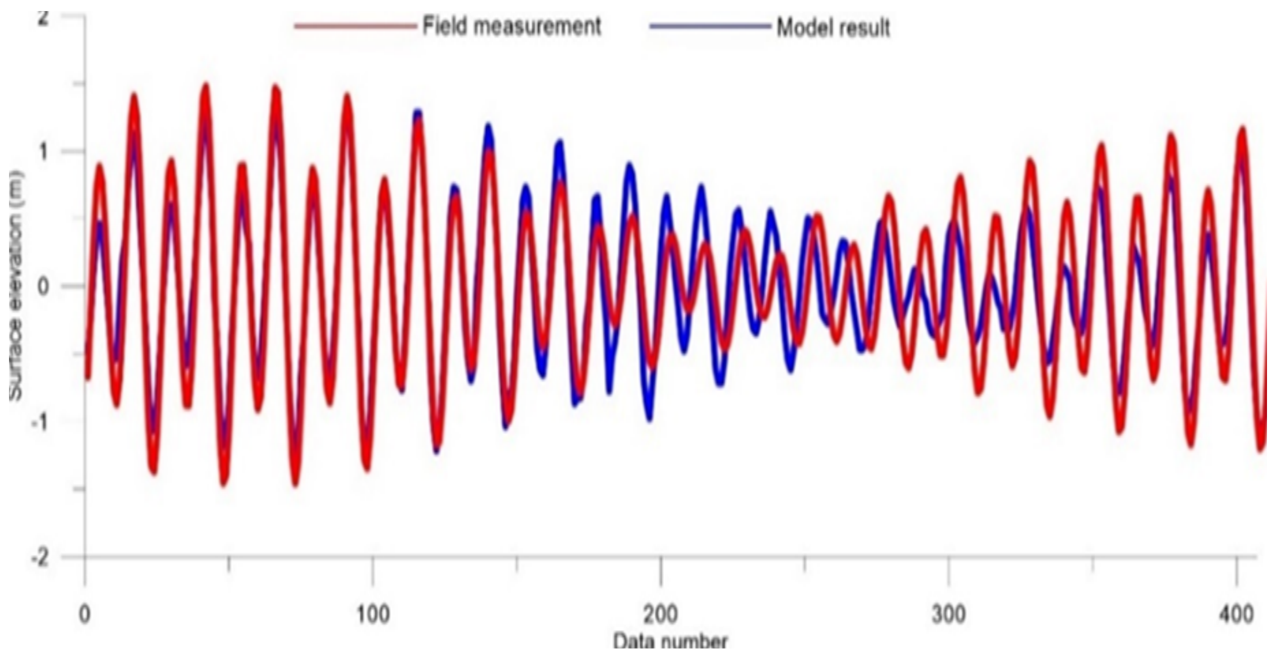


Figure 4. Flow model validation using tidal data.

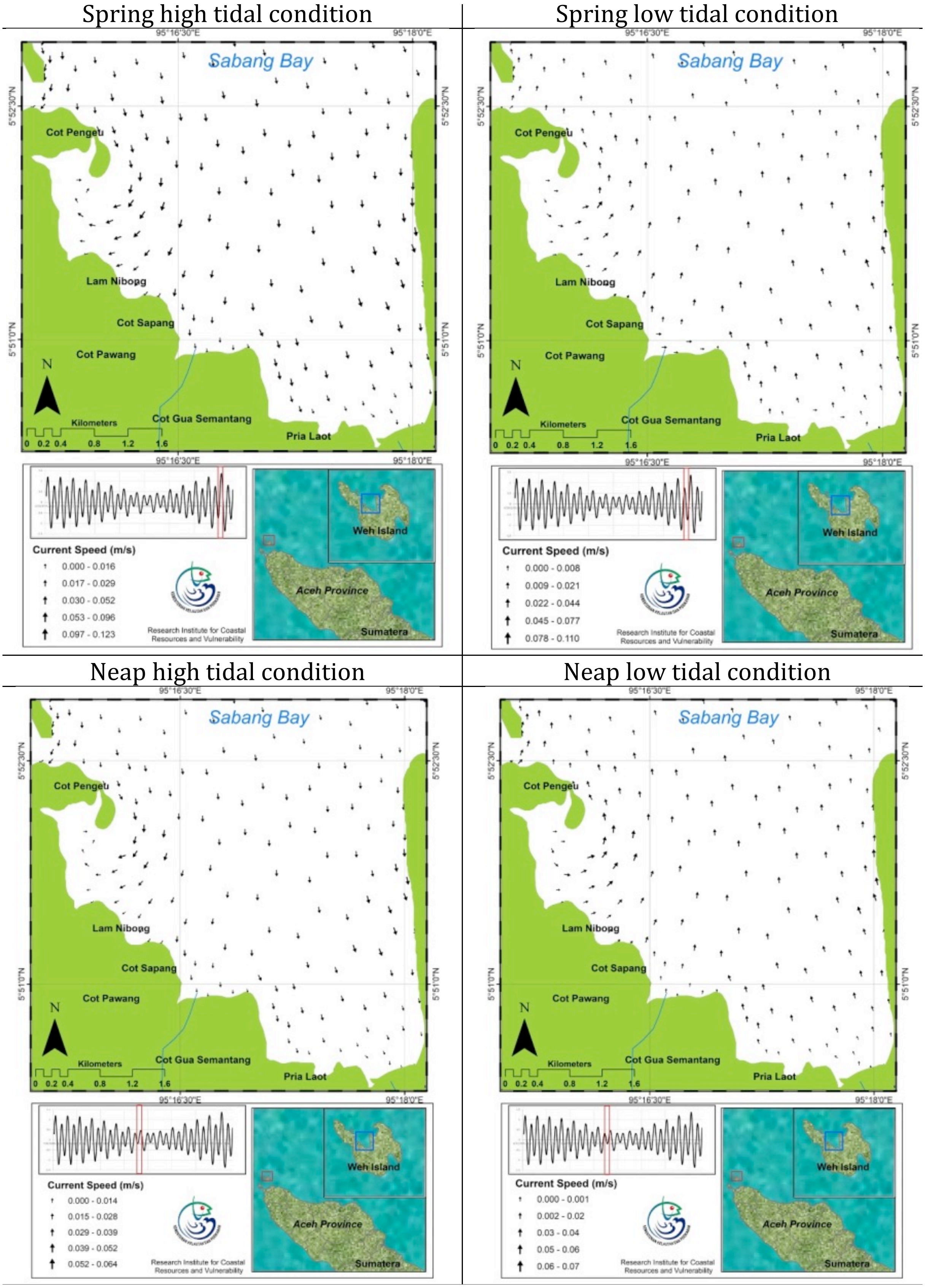


Figure 5. Tidal current patterns in Sabang Bay for four tidal extreme conditions.

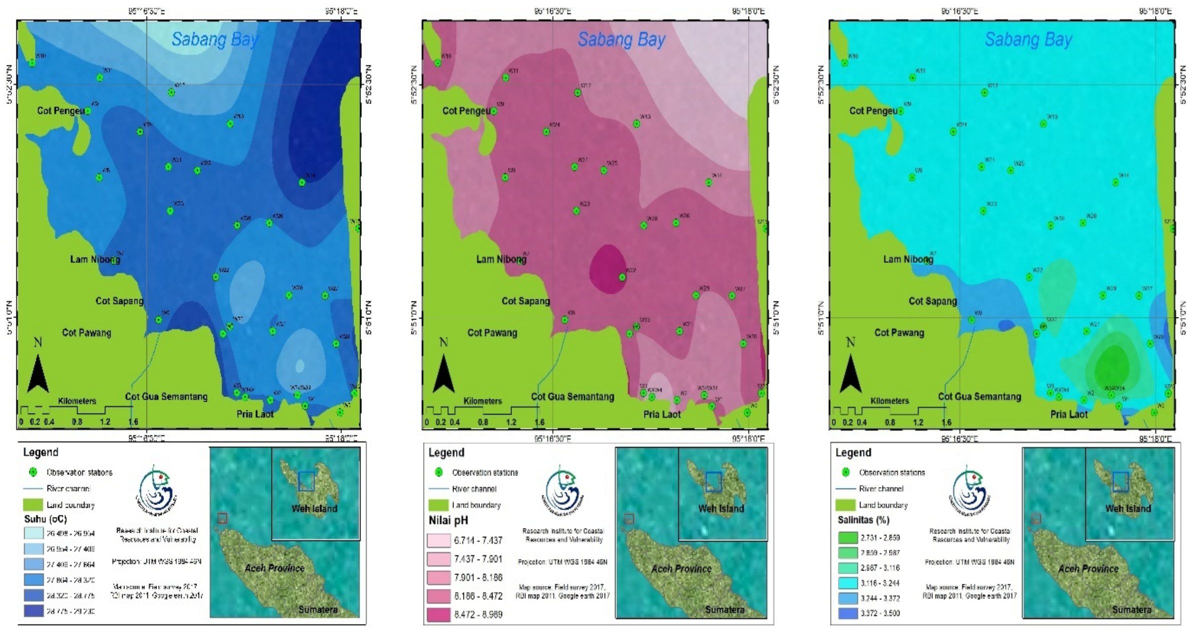
Current speed in Sabang Bay ranged from 0-0.123 m/s, 0-0.11 m/s, 0-0.064 m/s, and 0-0.07 m/s during spring high tidal condition, spring low tidal condition, neap high tidal condition, and neap low tidal condition respectively (Figure 5). Both spring and neap high tidal conditions the ocean current flows southeastward due to the wind provenance northwest and the higher level sea-sourced. Those conditions are vice versa during low tidal condition which the land-sourced materials are predominant.

The pattern of tidal current can determine the transport mechanism within the bay that sediment transport in the form of suspended material may influence the waters. The tidal-wave circulations may trigger the stronger turbulence and mixing in the bottom (Li and Zhong, 2009; Bayhaqi *et al.*, 2018). The semi-enclosed water area of Sabang Bay has a role in controlling the transport mechanism that is weaker within the bay due to the topographical regime (Newton *et al.*, 2014).

3.2. Water Quality Conditions

During the displacement toward low tidal condition, the temperature ranged from 26.5-29.23ºC (Figure 6a). The highest temperature value is observed in the coastal water area indicating the land-sourced influence. Temperature is the most important physical factor in the water that has a role in controlling biogeochemical processes, oxygen diffusion, microbial respiration, and phytoplankton survival ability (Agawin *et al.*, 2000).

pH has a special limitation in water which this parameter can control the oxidation process and carbon cycle influenced by CO_2 accumulation (ocean acidity). In Sabang Bay, pH ranged from 6.7-9 which shows the up-normal acidity level categorized into tend to be alkaline (Figure 6b). Those conditions prove that Sabang Bay is not affected by the CO_2 emission inducing higher acidity in the waters. The higher value of pH in several areas might be caused by the presence of *fumaroles hydrothermal vent* (Chen *et al.*, 2005).



a b c

Figure 6. Water quality distribution in Sabang Bay; a. Temperature distribution; b. pH distribution; and c. Salinity distribution.

Salinity ranged from 2.73-3.5 %, the highest salinity is observed in the area hot bubble (Blue polygon) (Figure 6c) which might be induced by the high temperature resulted from hydrothermal processes. According to Vandenbohede *et al.* (2014), presence of groundwater with a high temperature is key factor triggering salinization.

3.3. KJA Evaluation Based on Physical Condition of Sabang Bay

Based on the hydro-oceanography data obtained, we evaluate KJA compatibility in Sabang Bay by comparing the physical data required for KJA and the existing condition (Table 2). The location of KJA is suitable for mariculture in the offshore area (>2 km from the coastline). The depth within Sabang Bay is appropriate, the sloping bottom is very suitable for offshore KJA implementation. Wave height and significant wave height occupied the requirement for KJA. This condition is supported by wave-topography interaction within semi-enclosed water area so that KJA will not be damaged by storm-surge possibly occurred in the open ocean.

The current speed is less than the minimal requirement for KJA. The low circulation becomes the main factor in controlling the distribution of organic and inorganic materials sourcing from anthropogenic activities and KJA feeder waste. Moreover, the accumulation of waste may cause the over-enriched water area which induces blooming tendency (Cromey *et al.,* 2002). This issue will also disrupt the marine tourism activity in Sabang Bay.

Table 2. The evaluation of KJA compatibility in Sabang Bay.

No.	Parameter	KJA requirement	Information	Observed in Sabang Bay	Source
1	Location	>2km from the coastline, (1-6 km substantial)	Offshore: >2km Onshore:0.5-3 km Coastal: <50 m	>2 km	
2	Ocean depth	>50 m depth	Offshore: >50 m Onshore: 10-50 m Coastal: <10 m	>150 m	GEBCO
3	Wave height	< 9 meters, (1-3 m substantial)	Sheltered: <1.5 m Semi-exposed: <3.5 m Exposed: <6 m Offshore: <9m	0.3-1.2 m	Field measurement
4	Significant wave height	5 meters, (1-2 m substantial)	Offshore: 5 m Onshore: 3-4 m Coastal: 1 m	0.2-1 m	Field measurement
5	Current speed	0.5-1 m/s	Substantial	0-0.123	Field measurement +model result
6	Temperature	28-32^{o}C, range: 16-35^{o}C	Optimal	26.5-29.23^{o}C	Field measurement
7	pH	7.5-8	Optimal	6.7-9	Field measurement
8	Salinity	30-35 ppt, 0-36 ppt for mariculture	Optimal	27.3-35	Field measurement

The conditions of temperature, pH, and salinity are still suitable for mariculture even though pH value is higher in the several stations. Water quality condition is essential for supporting the growth of *lates calcaliver* that will be cultivated (Biswas *et al*., 2010). The important thing that needs to pay attention is the presence of *fumaroles hydrothermal vent* which tremendously controls the water quality degradation in Sabang Bay (Kurnio *et al*., 2015). If offshore KJA is installed, the water quality degradation will take place (dos Santos Simões *et al*., 2008).

Besides, the pollution waste resulted from KJA will contaminate the ecosystem beneath where *Sophie Rickmers* shipwreck and its biomass will be endangered, even though it uses *integrated multitrophic aquaculture* system to reduce the environmental impact of the fish feeder and waste, the pollution is undoubtedly avoided due to the calm water circulation within the bay. So that the KJA wastes cannot be well-distributed and tend to be settled in the sediment.

IV. CONCLUSIONS

Offshore KJA installation planning needs to reconsider the hydrodynamic characteristics. Due to the semienclosed water area of Sabang Bay and the interaction between tidal-wave-topography, the calmer water mass transfer results. This condition automatically will pollute the water due to the accumulation of remaining fish feeder wastes. Moreover, within the bay, there are a lot of attractions such as *Sophie rickmers* shipwreck site and hot bubble that become the most-dive place in Sabang Bay. The presence of offshore KJA wastes will disrupt and endanger those attractions which will also induce pollution in the surrounding due to the weak transport mechanism occurred.

This study only considers several physical factors required for offshore KJA installation. We suggest occupying the evaluation by completing the other chemical parameters needed such as substrate condition, redox potential, total suspended solids, visibility, dissolved oxygen, and nutrients (ammonia, nitrite, and nitrate). So that the evaluation of offshore KJA in Sabang Bay will be more appropriate.

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