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Hydro-Oceanographic and Water Quality Assesments As a Basis for the Development of Offshore Aquaculture in the Weh Island, Aceh Province, Indonesia

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Abstract – The waters of Weh Island, Aceh Province has potency become the area for offshore aquaculture. Offshore Floating Net Cages can be an appropriate technology in increasing the biomass cultivation in Weh Island waters. However, no feasibility study has been done. Therefore, this study aims to examine the suitability of offshore aquaculture locations in the East and South regions of Weh Island Based on Hydro-oceanography parameters. The parameters examined were water quality parameters such as temperature, brightness, pH, salinity and dissolved oxygen. In addition, we also examined the aspects of physical oceanography such as tides, currents and bathymetry. The results show that the water depth ranged from 0-57 m. The tidal type in the Weh Island waters is mixed tide prevailing semidiurnal with the tidal range of 1.9 m. The average of current speed ranged from 19.03-37.67 cm/s with the directions predominantly toward northwest and southeast. It is concluded that the water quality data show that the eastern and southern parts of Weh Island are categorized as the feasible locations for offshore aquaculture.

Keywords: Sabang, Hydro-oceanography, Fisheries, Offshore aquaculture, Floating net cages

Introduction

Weh Island located on the Aceh Province cosists of 16 villages from 18 Sub-district that are surrounded by coastal areas, thus the community's dependence on marine and fisheries resources are very high. Aceh province has a coastal line of 2310 km including 238,807 economic exclusive zone with at least 119 isles (Muchlisin, 2010; Bappeda, 2008). Therefore, fisheries are playing an important role in Acehnese people (Muchlisin *et al.*, 2012). Tuna is one of the commercial important fish occurred in Aceh waters with the production of tuna fish was 934.27 tons/year, skipjack 650.25 tons/year and tuna 631.70 tons/year (MMAF, 2017). The productions in the fisheries and marine sector that can be used as a trademark and core businesses of Weh Island.

One of the important factors supporting the strategic fisheries and marine yields is the existence of well-managed available port. There are 8 ports of TPI (Fish Landing Place) and 1 port of PPI (Indonesian Fisheries Port) spread over Weh Island (MMAF, 2017). One of the ports located in the south of Weh Island is in Keunekai, while the Ie Meulee port is in the north side. These ports are significant because they connect the Weh Island and the mainland of Sumatera. Besides having potential in capture fisheries, several locations in the waters of the Weh island also have the potential

for mariculture areas. However, there was no scientific information on the suitability location for the development of mariculture in this area. Ecological suitability assessment is important be performed before the aquaculture business is carried out to ensure that the aquaculture business will be successful and profitable (Muchlisin, 2012; Muchlisin, 2019).

Several previous related studies in this area have been reported by several authors., for instance, Wisha *et al.* (2018) defined the nutrient enrichment and its influence on phytoplankton abundance which is related to the wtaer condition in Keunekai. Wisha and Ondara (2018) stated that the organic carbon and nitrogen has an impact on surrounding environment, this study is related to offshore aquaculture where the fish-feeding wastes will tremendously impact the water. Another previous research which was also diccussing about offshore aquaculture in Weh Island was published by Wisha *et al.* (2019). Thus, a study assessing the suitability of offshore aquaculture, that will be impelemented, based on hydro-oceanography conditions in the Weh Island is essential. Therefore, the objective of the present study was to examine the suitability of the Ie Meulee and Keunekai waters for the development of offshore aquaculture areas.

Materials and Methods

Time and site

This study was conducted on March 11-17th, 2017. We focused on the two main sites that are Keunekai and Ie Meulee which become the area of significance (Figure 1). The field surveys were done by measuring tides, winds, currents, bathymetry, and water quality data. According to the local information that the offshore fish cage aquaculture will be implemented in those two areas. Thus, it will be appropiate if we do assessment based on hydro-oceanography data.

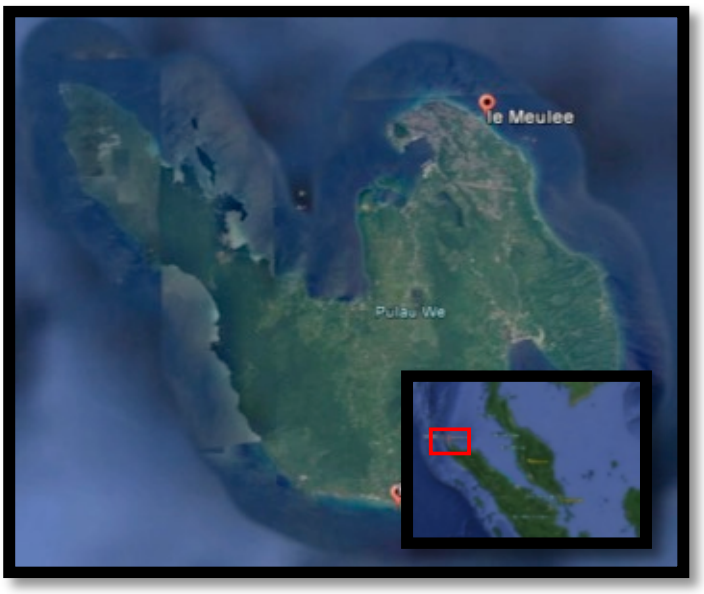

Figure 1. Research location on Weh Island, Aceh Province, Indonesia

Data collection

The process of collecting primary data from direct measurements in the field included measuring bathymetry and observing tidal data. Retrieval of field data were carried out on March 2017 in the Sabang waters. The depth of the sea waters is measured using a dual frequency transducer that emits low frequency and high frequency waves. Low frequency waves can penetrate

the soft layer while high frequency waves can only radiate to the bottom of the waters. As a dual frequency that is discrete, the two return signals do not interfere with each other. The transducer is connected to the GPS to find out the position of the depth as well as a navigation guide for the casting line. The method used to measure is an acoustic method using echosounder Echo-track CVM Teledyne Odom Hydrographic Single Beam. Correction of bar-check transducer is done before and after measurement as a calibration of depth data that has been determined to the depth of the correction bar-check transducer carried out before and after measurement as a calibration of depth data that has been determined to the depth of the transducer.

Primary data collection was carried out on March 2017. The survey was done by applying underway measurement using boat by which we moved station to station during the same tidal condition. In this study, we only surveyed the water condition during the low tidal condition thereby considering the anthropogenic influences. The chemical and physical water quality parameters measured are TSS, pH, DO, salinity, temperature, turbidity, and brightness. Water sampling was planned 23 observation stations representing the water condition around the Keunekai and Ie Meulee in accordance with the possible area of Offshore Floating Net Cage establishment. But unfortunately, we only sampled 17 observation stations due to the erratic weather condition. Bathymetry data were obtained by surveying the chosen areas using Echo-sounder Echo-track CVM Teledyne Odom Hydrographic single beam. While, oceanographic data such as tides and currents were measured using Acoustic Doppler Current Profiler (ADCP-Nortek). Figure 3 shows the principles of ADCP measurement used in this study. The primary data retrieved from the field survey will be analyzed using water parameter suitability table for the offshore fisheries (Radiarta *et al.*, 2006; Beveridge, 1996; Mayunar *et al.,* 1995; Ismail *et al.*, 1995).

Figure 2. Transducer set-up and deployment uring field survey

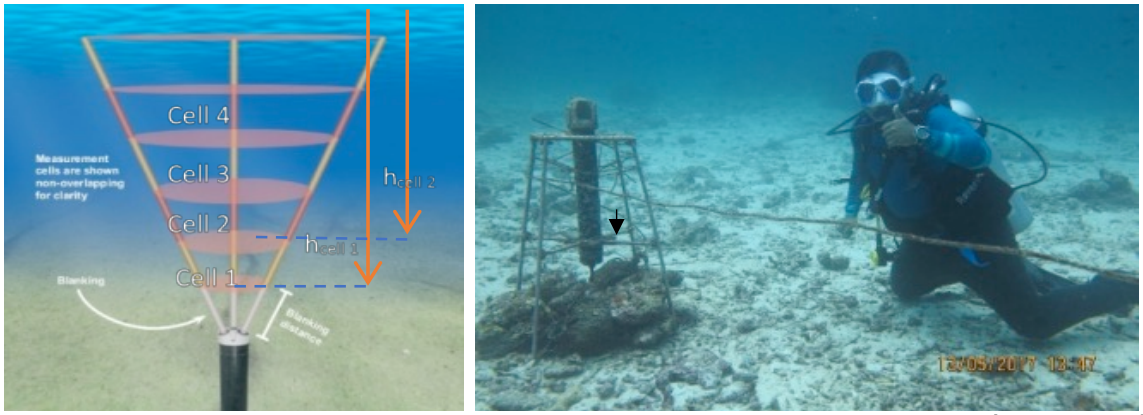

Figure 3. The principles of ADCP measurement used in this study (Long: 95.221^0; Lat :5.906^0)

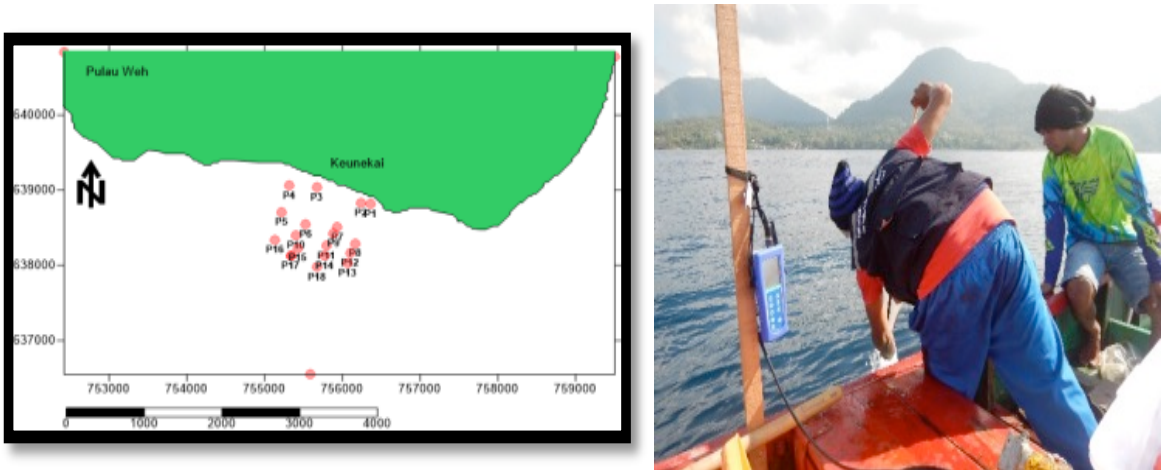

Figure 3. Sampling locations and processes in Keunekai

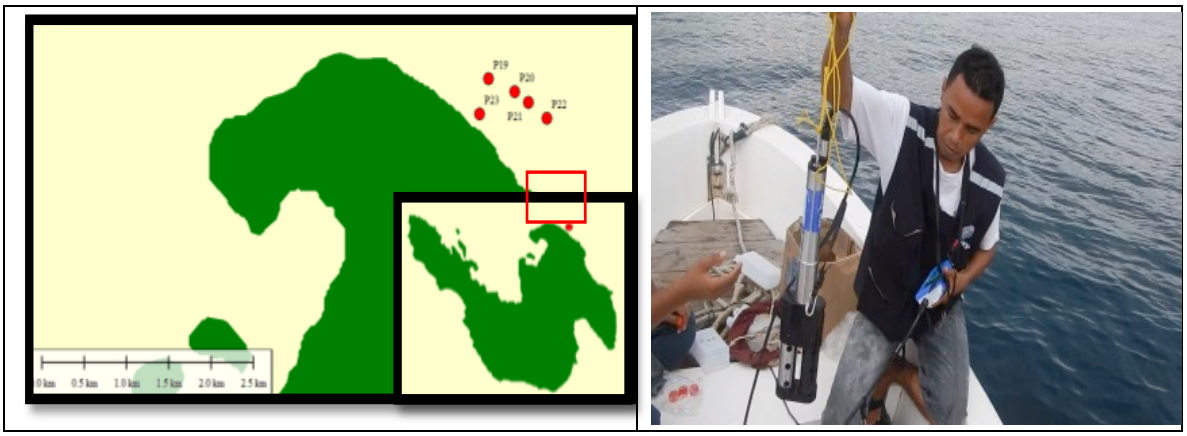

Figure 4. Sampling locations and processes in Ie Meulee

Data analysis

Some parameters were measured directly using the Water Quality Checker TOA DKK and several parameters were carried out in the laboratory analysis. Water samples from the study site were analyzed in the Industrial Research and Standardization Center of Banda Aceh. The verification of the suitability parameters of the water quality parameters for deep sea fisheries will be carried out in Table 1.

Table 1. Suitability of water parameters for deep sea fish cultivation

No	Parameter	Weight	Very Suitable (S1)	Quite appropriate (S2)	Conditionally (S3)	Not Suitable (N)
1	Depth (m)	2	10 - 20	20 – 25	25 – 30	< 10 & > 30
2	Brightness (m)	1	> 3	2 – 3	1 – 2	< 1
3	Current speed (m/s)	3	5 – 15	15 – 25	25 – 35	< 5 & > 35
4	Temperature (^{0}C)	3	28 – 32	25 – 28	20 – 25	< 20 & > 32
5	Salinity (ppt)	3	31 – 35	28 – 31	25 – 28	< 25 & > 35
6	pH	2	> 7	6 – 7	4 – 6	< 4
7	DO (mg/l)	2	> 7	5 – 7	3 – 5	< 3

The criteria used as a basis for determining the feasibility of marine fish cultivation refer to the results of Ahmat *at al.* (1991), Atjo (1992), Mubarak *et al.* (1990), Radiarta *et al.* (2005) and Utojo *et al.* (2007). The determination of cultivation suitability for each parameter depends on the influence of cultivation commodities. Scoring systems 1 to 4 are used in this study with the detail of the suitability level as follows:

(1) Not feasible / inappropriate: can be used for cultivation, but requires considerable cost, energy and time.
(2) Fairly feasible / conditional: can be used for cultivation, but requires considerable cost, energy and time.
(3) Decent / appropriate: can be used for cultivation, with little need of cost, energy and time.
(4) Very feasible / very suitable: suitable for use in marine fish cultivation in floating nets.

The weighting of each parameter was determined based on the dominant parameters of the appropriateness of the feasibility of the sea cultivation land. These parameters were sorted from the most influential, because each parameter has a different role in supporting commodity life. Parameters that have a large impact will get greater value than parameters that do not have a large impact (Hidayat and Soekardi, 1995). The biggest weight is 3 (three) and the smallest is 1 (one) so the total weight is 16.00 (100%). Weight multiplication with a rating scale will get the final score (score) from these factors. Then the total score of all the limiting factors of each column of the rating scale is calculated from 1 to 4. Then the percentage of the score is measured by units per -4, meaning that the value 4 gets a value of 100% and the value of one gets a value of 25%. Scoring compatibility is determined based on the value of weighting score.

Results

The depth of the waters in Keunekai and Ie Meulee ranges from 0 to 57 meters. The appropriate depth for KJA is 588 meters from the shoreline and to the farthest point from the mainland 865 meters, with a depth of about 30 meters. These water depth results have been corrected using tidal data and the depth of transducer during measurement. So that, the bathymetry data will be more appropriate representing the real condition in the field.

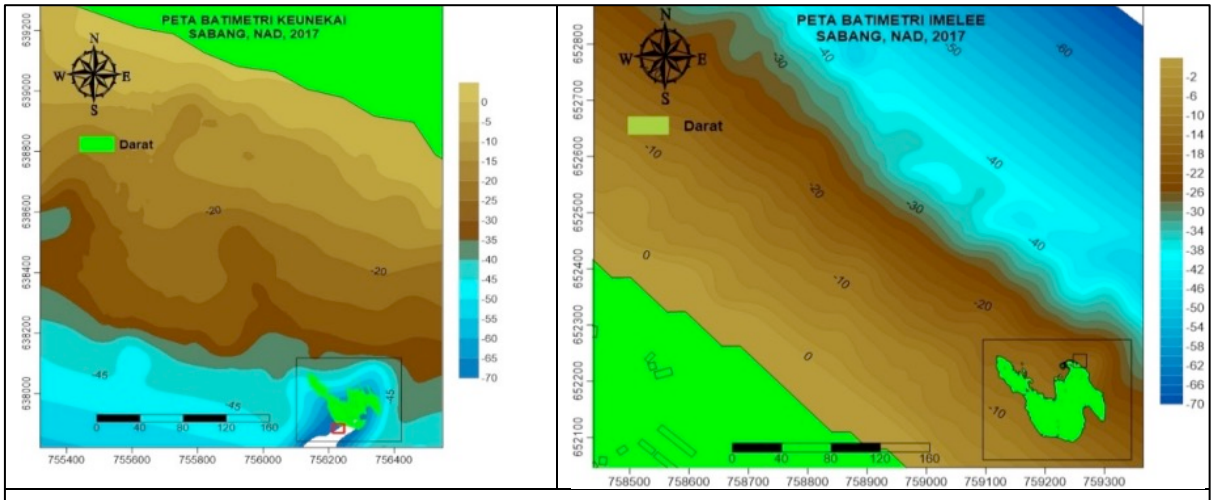

Figure 5. Bathymetry conditions in Keunekai (left) and Ie Meulee (right)

Hydrodynamics

The measurement of current direction and magnitude in Ie Meulee using ADCP which is placed on the coordinates Long 95.22091; Lat 5.0683. The object measured by ADCP is the speed of the particles in the water because the nature of the motion of the character follows the movement of water. The tidal type in the waters of Ie Meulee is mixed tide prevailing semidiurnal in which the elevation changes will occur twice as the high tidal condition and twice as the low tidal condition in a day, but the first elevation formed is higher than the second one. This can be seen visually from the tide chart for 29 days (08 March - 05 April 2017). In the range of data obtained, the highest tidal evelation reached 77,54 cm and the lowest is -69.66 cm, and the tide peak is 147.19 cm. Based on the calculation and analysis of the tidal Admiralty table for 29 days, several tidal components were obtained in the Ie Meulee waters as in Table 1.

Tidal types in the waters of Weh Island were reinforced again with the Formzahl, which was obtained from the calculation of the amplitude of the single tidal main component (AK1 and AO1) and the amplitude of the main components of multiple tides (AM2 and AS2), which is equal to 0.2616. Formzahl of $0.25 \leq F < 1.5$ means to have a mixed tide prevailing semidiurnal tidal type. Sea level rise that occurs every year is inversely proportional to the area of inundation produced (Ondara *et al.*, 2016)

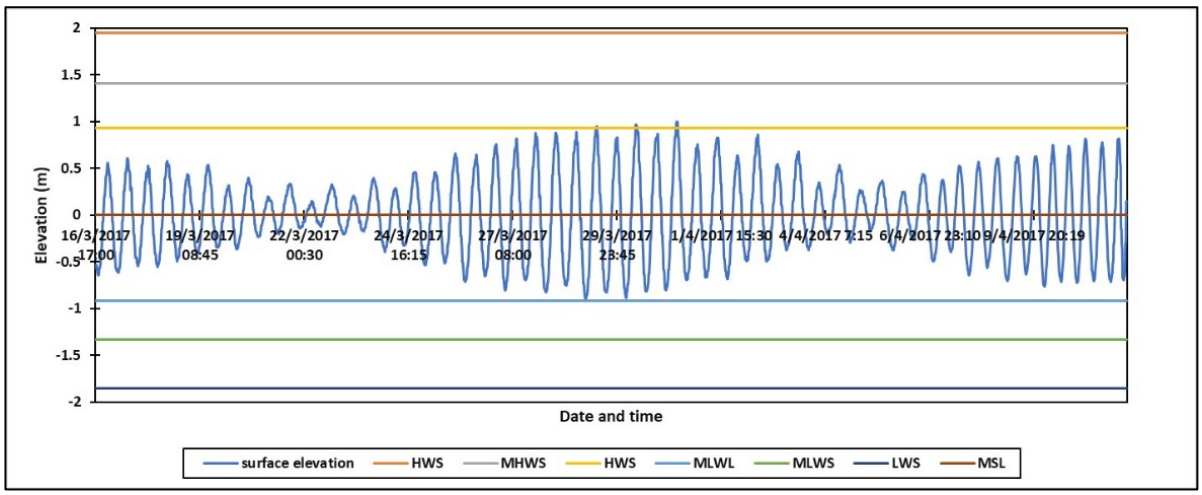

Figure 6. Tidal graph of the waters of Weh Island and its surroundings

Table 2. The main tidal components Sabang and its surroundings

	S0	M2	S2	N2	K1	O1	M4	MS4	K2	P1
A (cm)	1.26	40.36	18.21	7.93	10.51	4.81	0.05	0.09	4.92	3.47
g°		80.69	116.68	74.11	206.95	180.97	323.40	17.99	116.68	206.95

Current characteristics in Ie Meulee

Current velocity measured at 5 different depths is divided into 5 cells, namely cell 1 at a depth of 3.5 m; cell 2 at a depth of 5.5 m; cell 3 at a depth of 7.5 m; cell 4 at a depth of 9.5 meters, cell 5 at a depth of 11 meters and cell 6 at a depth of 12.5 meters. Surface velocity (cell 1) ranges from 1.5-85.6 cm/s, the current velocity in the water column (cell 3) ranges between 0.4-75.4 cm/s, near-base current velocity (cell 5) ranges from 0.30 to 55 cm/s. Current velocity values in the surface, water columns, and bottom waters range from 0.3 – 83.2 cm/s with an average of 19.03 cm/s. The

current direction in the water column and bottom predominantly moves northwestward and southeastward, respectively. The current direction moves parallel to the coastline proving that longshore current takes place. Ie meulee coastline is directly exposed by waves, so that the wind-driven current is possibly dominant in this water area. On the surface of these waters, current velocities range from 1.1 – 96.4 cm/s and an average of 37.67 cm/s (Figure 7).

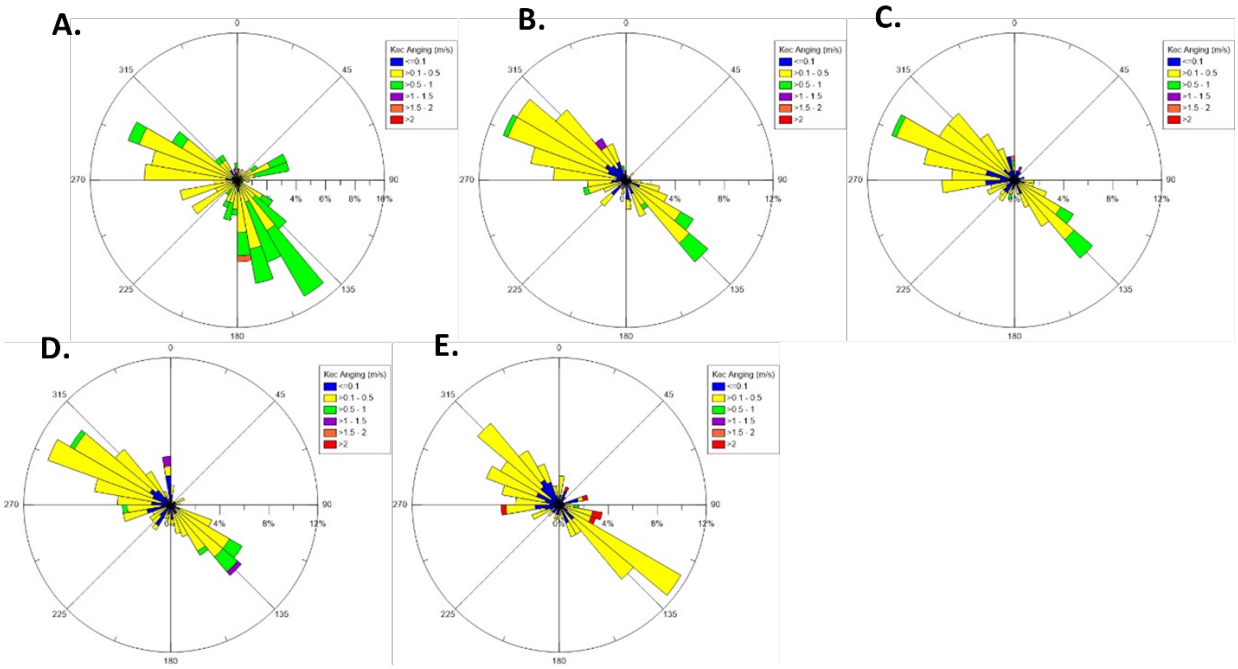

Figure 7. Ie Meulee current rose at five different depths (A) surface waters, (B) 3 m, (C) 5 m, (D) 7 m and (E) 10 m

Current characteristics in Keunekai

Current velocity measured at five different depths is divided into 5 cells, namely cell 1 at a depth of 1.5 m; cell 2 at a depth of 3.5 m; cell 3 at a depth of 5.5 m; cell 4 at a depth of 7.5 meters and cell 5 at a depth of 11 meters. Surface velocity (cell 1) ranges from 1.9-8.26 cm/s, current velocity in the water column (cell 3) ranges between 1.7-88.8 cm/s, current velocity near the base (cell 5) ranges from 0.30 to 64.90 cm/s (Figure 8). At the measurement date of March 14, 2017 at 3:00 p.m. using Automatic Weather Station (AWS), it recorded that wind-driven current anomaly is likely to be affected by the storm surge that occurred at that time, in which the wind speed reached 8.5 m/s. The deeper the velocity of the current begins to decrease and does not spread, it indicates that the influence of the wind will decrease along with the increase in the depth of the water, besides the influence of the basic obstacles and density also affects the vertical distribution of currents in the waters.

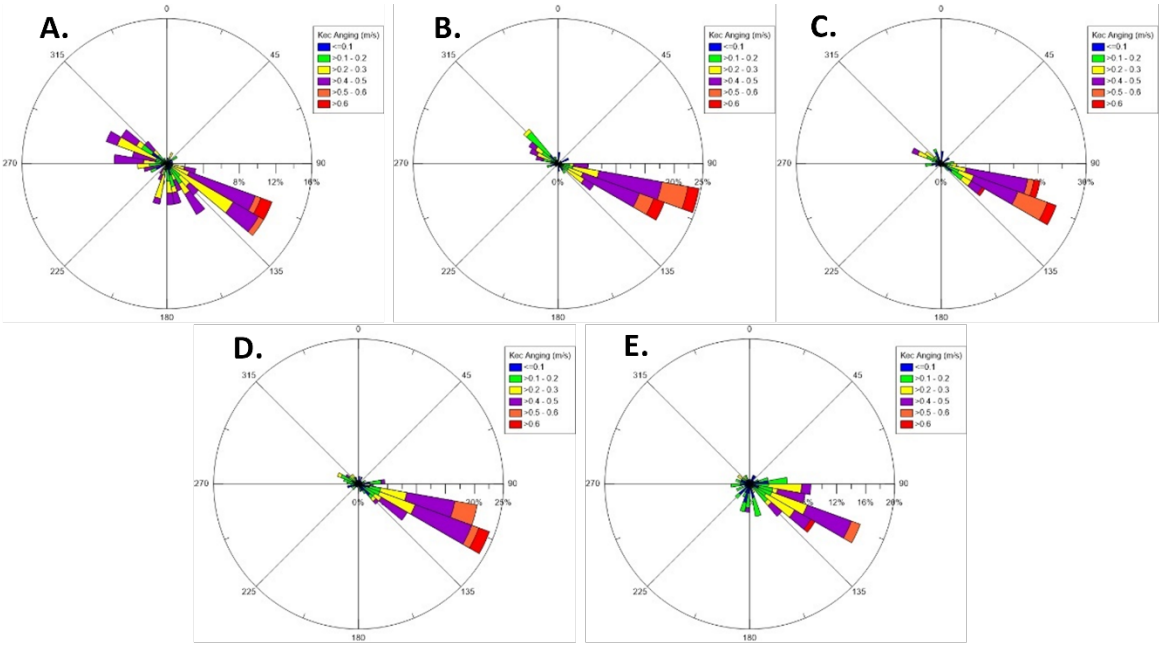

Figure 8. Keunekai Current rose at five different depths (A) surface waters, (B) 3 m, (C) 5 m, (D) 7 m and (E) 10 m

Water quality conditions

Figure 9 shows that water temperature ranges from 29.40 ^{0}C to 29.9 ^{0}C with the average value of 29.78 ^{0}C. The difference in water temperature is related to the difference in time in in situ measurements during the field measurement. The measurement of salinity values ranged from 30.8 to 31.4 ppt with an average value of 31.18 ppt. Salinity values do not show the very significant differences. The results of dissolved oxygen ranging from 4.12 mg/l to 4.70 mg/l. If referring to Minister of Environment Decree No. 51 of 2004 concerning sea water quality standards, this condition is not good because dissolved oxygen is below 5 mg/l. While, for pH values are around 8.25-8.36 which those ranges belong to alkaline water condition. The condition of pH is slightly high for marine biota but it is still acceptable for aquaculture. Visual observation shows that the Keunekai and Ie Meulee waters are in good and clear conditions.

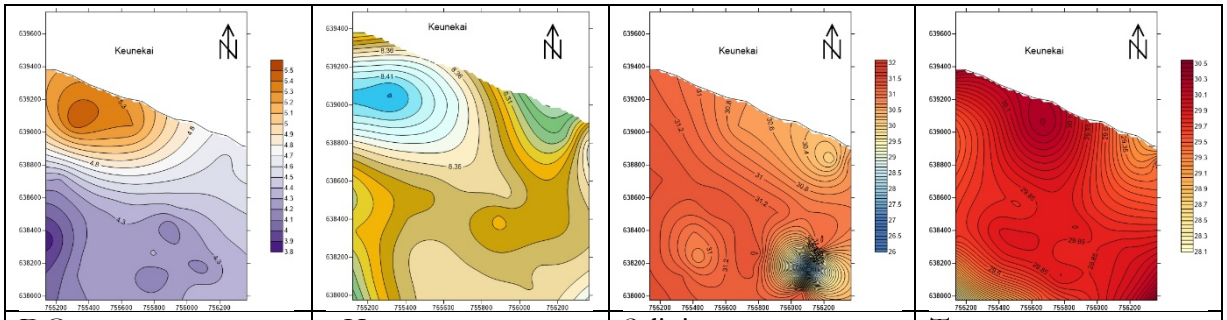

Figure 9. Distribution of water quality parameters in Keunekai

Table 3. Survey results of Weh Island waters

Station	coordinate		*depth*	Brightness	Current speed	Temp	Salinity	pH	DO
	Long	Lat	(m)	(m)	(cm/s)	(Celsius)	(ppt)		(mg/l)
1. Keunekai Waters									
P1	5.7723	95.3074	4.3	4.3	10	29.8	31.4	8.34	4.3
P2	5.7719	95.3111	2.95	2.95	10	29.8	31.2	8.35	4.4
P3	5.7699	95.3131	0.7	0.7	10	29.9	31.1	8.34	4.4
P4	5.7711	95.3106	7.05	7	10	29.9	31.1	8.33	4.1
P5	5.7709	95.3063	26.24	>10	10	29.9	31.0	8.34	4.2
P6	5.7696	95.3098	44.77	>10	10	29.8	31.4	8.34	4.3
P7	5.7676	95.3122	46.49	>10	10	29.9	31.2	8.35	4.4
P8	5.7694	95.3065	26.38	>10	10	29.8	30.8	8.35	4.3
P9	5.7685	95.3056	27.09	>10	10	29.4	31.3	8.34	4.2
P10	5.8978	95.3424	39.15	>10	10	29.8	31.4	8.29	4.3
P11	5.8954	95.3458	44.28	>10	10	29.8	31.4	8.25	4.4
P12	5.7723	95.3074	25.94	>10	10	29.5	30.8	8.36	4.7
2. Ie Meulee Waters									
P13	5.8990	95.3396	41.47	>10	10	29.8	31.3	8.27	4.33
P14	5.8978	95.3424	52.64	>10	10	29.8	31.4	8.29	4.34
P15	5.8968	95.3438	52.41	>10	10	29.8	31.4	8.27	4.34
P16	5.8954	95.3458	56.92	>10	10	29.8	31.4	8.25	4.36
P17	5.8958	95.3386	5.92	>10	10	29.6	31.4	8.24	4.11

The assessment of offshore aquaculture based on hydro-oceanography parameters

Based on scoring results (Table 4). All stations show the good value for offshore aquaculture implementation by which the scores resulted ranged from 70-84 %. The most suitable area is Ie Meulee where the higher scoring is resulted. Accoring to the local fisherman, Ie Meulee becomes the most fertile area in the Weh Island due to the highest coral cover existed. While, the lower scores belong to Keunekai stations because this area has been experiencing major damage due to the mass bleaching occurred in 2016 (Wisha *et al.*, 2018) and the utilisation of fish bombing severa years ago. Even though Keunekai is less-suitable for developing mariculture, water quality data observed in this area is still good for supporting fish growth and high productivity.

Table 4. Recapitulation of assessments and weighting at each observation point.

Assessment																	
Titik	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
depth	2	1	1	4	1	1	1	1	1	1	1	1	1	1	1	1	3
Clarity	3	1	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Current	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Temp	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Salinity	4	4	4	4	4	4	4	3	4	4	4	3	4	4	4	4	4
pH	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
DO	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Table 4 continued…

Weighting																	
depth	4	2	2	8	2	2	2	2	2	2	2	2	2	2	2	2	6
Clarity	3	1	1	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Current	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Temp	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Salinity	12	12	12	12	12	12	12	9	12	12	12	9	12	12	12	12	12
pH	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
DO	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Score (%)	77	70	70	84	75	75	75	70	75	75	75	70	75	75	75	75	81

Discussion

According to the results of bathymetry survey, the appropriate area is located near the coastline where the depths are around 0-30 meters. While the deeper area might be impossible for developing offshore aquaculture because the deeper the water depth, the higher the wave-induced current energy evokes. Waves are the main factors possibly hamper the existence of offshore floating aquaculture. Strong currents induced by surface wind waves has a significant role in controlling the long-term usage of offshore fish cage. Moreover, tidal current also triggers the transport mechanism in the semi-enclosed water area such as Keunekai and Ie Meulee which is related to the accumulation of aquaculture wastes. The lower the transport mechanism, the higher accumulation of wastes resulted. This condition might influence the tendency of nutrient enrichment that will disrupt the biogeochemical cycle and biota survival ability (Wisha *et al*.. 2018).

The current speeds in the surface are higher than in the water column and the surface bottom. This condition proves that the influence of wind, which is quite dominant, also occurs in these waters, which more influential than the effect of the pressure gradient on current events. It can be seen in Figures 6 and 7, where the current velocity pattern occurs, such as sea level change conditions. If the current pattern in a water shows a fluctuating pattern following tides, then tidal currents are the dominant currents occurring in these waters. In addition, to the pattern of the velocity of the ocean currents, it is also observed the occurrence that when going to low tide or when going to the peak water level the current velocity becomes larger. Tanto *et al.* (2017) mentioned that for a moment going to ebb and shortly to the tide, the speed condition of ocean currents can be maximum.

The current direction domination in Keunekai is oppositely different with Ie meulee where it tends to move northwestward, even though the southeasterly current was also observed. This is because of the the different location of those two significant regions where Ie meulee is directly bordered by the Bay of Bengal while Keunekai located in the southern Weh Island which controlled by the interaction of atmosphere-ocean in the Indian Ocean. The great water mass movement through Bengal Bay has a special role in triggering internal wave-induced current (Lee *et al*., 2016) which may hamper if the offshore aquaculture is implemented in the Weh Island.

Different from physical-oceanography factors, the water quality data retrieval shows the good condition of Weh Island waters which is normal compared to the quality standard established by the Ministry of Environment. Only one parameter that is under the standard that is dissolved oxygen (DO). DO becomes a limiting factor in the waters which is a chemical indicator of pollution (Sharifinia *et al*., 2016). The lower value of DO will show the condition toward anoxia which is related to the declination of oxygen penetration to the water. Based on the data obtained, DO concentration is around 4 mg/l which is still suitable for certain biota (Kiko *et al*., 2016). The variation in dissolved oxygen content is caused by the movement and mixing of water masses and

the daily cycle of biogeochemical (Tsementzi *et al.*, 2016). The results of scoring show that the average value of 74 % indicating that Keunekai and Ie Meulee are feasible for developing offshore aquaculture. This study will recommend that the implementation of floating fish cage aquaculture is feasible based on water quality data in which it can support the aquaculture that will be made, but for the important consideration, the Weh Island is influenced by some ocean-atmosphere interactions which may potentially damage the floating fish cage because during certain periods, the high storm surge is occurred. This will threaten the existence of the long-term offshore aquaculture. Moreover, the selection of fish cultivated is also important in accordance with the hydro-oceanography condition of Weh Island (Chen *et al.*, 1977; Kohno *et al.*, 1988). Thus, proper handling of offshore aquaculture needs an extra attention to yield a satisfying result.

Conclusions

Keunekai and Ie Meulee waters were in the category "feasible" to be developed for grouper fish aquaculture. Nevertheless, it is necessary for further consideration that the depth conditions of the waters and the potential changes in direction and velocity of currents can be the main factors in deciding the success of KJA-based aquaculture activities. Moreover, the selection of fish species that will be cultivated at the site is also important. Thus, the implementation of offshore aquaculture project also depends on the proper handling of its operations so that failure risks can be diminished relatively, and the results obtained can take place sustainably.

References

Affan, J. M. 2012. Identifikasi lokasi untuk pengembangan budidaya keramba jaring apung (KJA) berdasarkan faktor lingkungan dan kualitas air di perairan pantai timur Bangka Tengah. Depik Jurnal Ilmu-Ilmu Perairan. Pesisir dan Perikanan, 1(1): 78-85

Ahmad, T.P., Imanto, T., Muchari, A.B., Sunyoto, P., Slamet, B., Mayunar, R.P., Murtiningsih, S. 1991. Operasional pembesaran ikan kerapu dalam keramba jaring apung. Laporan Teknis Balai Penelitian Perikanan Budidaya Pantai. Maros. 59pp.

Atjo, H. 1992. Potensi sumberdaya kekerangan Kabupaten Barru. Dalam Mansur. A. (Ed.). 1992. Prosiding temu karya ilmiah potensi sumberdaya kekerangan di Sulawesi Selatan dan Tenggara. Watampone. Hal 8 – 10.

Bappeda. 2008. Geografi pemerintah Aceh. Badan Perencanaan Pembangunan Daerah. Provinsi NAD. Banda Aceh.

Beveridge, M.C.M. 1996. Cage aquaculture (eds 2nd). *Fishing News Books LTD*. Farnham. Surrey. England. 352 p.

Chen, F.Y., Chow, M., Chao, T.M., Lim, R. 1977. Artificial spawning and larval rearing of the grouper. Epinephelus tauvina (Forskal) in Singapore. Singapore Journal of Primary Industries, 5(1):1-21.

Hidayat, A.M., Soekardi, P. 1995. Kajian kesesuaian lahan untuk mendukung pembangunan perikanan pantai dan pertanian di daratan Kasipute-Lainea. Sulawesi Tenggara. Dalam Laporan Akhir Hasil Penelitian potensi dan hasil kesesuaian lahan untuk pengembangan perikanan

Ismail, W., Wijono, A. 1995. Lingkungan laut: Pelestarian dan pengelolaannya bagi lahan budidaya perikanan. Prosiding temu usaha pemasyarakatan teknologi keramba jaring apung bagi budidaya laut. Puslitbang Perikanan. Badan Litbang Pertanian, 157 – 171.

Kiko, R., Hauss, H., Buchholz, F., Melzner, F. 2016. Ammonium excretion and oxygen respiration of tropical copepods and euphausiids exposed to oxygen minimum zone conditions. Biogeosciences (BG), 13(8): 2241-2255.

Kohno, H.M., Duray, J. Juario. 1988. State of grouper lapu-lapu culture in the Philippines. SEAFDEC Asian Aquaculture, 10(2): 4-8.

Lee, C. M., Jinadasa, S. U. P., Anutaliya. A., Centurioni. L. R., Fernando. H. J., Hormann. V., Wijesekera, H. W. 2016. Collaborative observations of boundary currents. water mass variability. and monsoon response in the southern Bay of Bengal. Oceanography, 29(2): 102-111.

Mayunar, R., Purba, P., Imanto, T. 1995. Pemilihan lokasi untuk budidaya ikan laut. Prosiding temu usaha pemasyarakatan teknologi keramba jaring apung bagi budidaya laut. Puslitbang Perikanan. Jakarta 12 – 13 April. No. 38: 179 – 187.

Muchlisin, Z.A. 2010. Diversity of freswater fishes in Aceh Province. Indonesia with emphasis on several biological aspects of the depik (*Rasbora tawarensis*) an endemic species in Lake Laut Tawar. Ph. D Dissertation, Universiti Sains Malaysia, Penang.

Muchlisin, Z.A. 2012. Studi pendahuluan kualitas air untuk pengembangan budidaya perikanan di Kecamatan Sampoinit Aceh Jaya Pasca Tsunami. Biospecies, 2(1): 10-16.

Muchlisin, Z.A., Fadli, N., Nasution, A.M., Astuti, R., Marzuki, Musni, M. 2012. Analisis subsidi perikanan non BBM di Kabupaten Aceh Besar. Provinsi Aceh. Depik, 1(3): 175-182.

Muchlisin, Z.A. 2019. Pengantar akuakultur. Universitas Syiah Kuala Press. Banda Aceh.

MMAF. 2016. Laporan Kinerja KKP 2016. Kementerian Kelautan dan Perikanan. Jakarta

Mubarak, H., Ilyas, S.,Ismail, W., Wahyuni, I.S., Hartati, S.H., Pratiwi, E., Jangkaru, Z., Arifuddin, R. 1990. Petunjuk Teknis Budi Daya Rumput Laut. Puslitbang Perikanan. PHP/KAN/PT/13/1990. Jakarta. 93 pp.

Ondara, K., Wisha, U.J. 2016. Simulasi numerik gelombang (spectral waves) dan bencana rob menggunakan flexible mesh dan data elevation model di Perairan Kecamatan Sayung. Demak. Jurnal Kelautan: Indonesian Journal of Marine Science and Technology, 9(2): 164-174.

Pranowo, S., Murtiningsih. 1991. Operasional pembesaran ikan kerapu dalam keramba jaring apung. Laporan Teknis Balai Penelitian Perikanan Budidaya Pantai. Maros. 59 p.

Purnawan, S., Zaki, M., Asnawi, T.M., Setiawan, I. 2015. Studi penentuan lokasi budidaya kerapu menggunakan keramba jaring apung di perairan Timur Simeulue. DEPIK Jurnal Ilmu-Ilmu Perairan. Pesisir dan Perikanan, 4(1): 40-48.

Radiarta. I.N., Saputra, A., Priono, B. 2005. Identifikasi kelayakan lahan budidaya ikan dalam keramba jaring apung dengan apikasi sistem informasi geografis di Teluk Pangpang. Jawa Timur. Jurnal Penelitian Perikanan Indonesia, 11(5): 1-13.

Radiarta, I.N., Prihadi, T.H., Saputra, A., Haryadi, J., Johan, O. 2006. Penentuan lokasi budidaya ikan KJA menggunakan analisis multikriteria dengan SIG di Teluk Kapontori. Sultenggara. Jurnal Riset Akukultur, 1(3): 303 -318.

Sharifinia, M., Mahmoudifard, A., Namin, J.I., Ramezanpour, Z., Yap, C.K. 2016. Pollution evaluation in the Shahrood River: Do physico-chemical and macroinvertebrate-based indices indicate same responses to anthropogenic activities?. Chemosphere, 159: 584-594.

Tanto, T.A., Wisha, U.J., Kusumah, G., Panowo, W.S., Husrin, S., Ilham, I., Putra, A. 2017. Karakrteristik arus laut perairan Teluk Benoa, Bali. Jurnal Ilmiah Geomatika, 23(1): 37-48.

Tsementzi, D., Wu, J., Deutsch, S., Nath, S., Rodriguez-R.L.M., Burns , A.S., Stone, B.K. 2016. SAR11 bacteria linked to ocean anoxia and nitrogen loss. Nature, 536(7615): 179.

Utojo, A., Mansyur, A.M., Pirzan, B., Tarunamulia, P. 2007. Identifikasi kelayakan lahan untuk pengembangan usaha budidaya laut di Teluk Saleh. Nusa Tenggara Barat. Jurnal Penelitian Perikanan Indonesia, 10(5): 1-18.

Wisha, U.J., Ondara, K., Ilham, I. 2018. The Influence of Nutrient (N and P) Enrichment and Ratios on Phytoplankton Abundance in Keunekai Waters. Weh Island. Indonesia. Makara Journal of Science, 187-197.

Wisha, U.J., Ondara, K. 2018. Total organic carbon and dissolved organic nitrogen in the upper water column of Keunekai Waters, Weh Island, Indonesia: an overview of mass coral mortality impacts. In IOP Conference Series: Earth and Environmental Science, 126(1): 012037.

Wisha, U.J., Rahmawan, G.A., Ondara, K., Gemilang, W.A., Dhiauddin, R., Ridwan, N.N.H. 2019. Offshore floating fish cage aquaculture development planning evaluation based on hydro-oceanography conditions in Sabang Bay, Weh Island. Jurnal Ilmu dan Teknologi Kelautan Tropis, 11(1):151-162.