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Placement of Floating Net Cages Cultivation System Based on Current Dynamics Model in the Semak Lagoon, Indonesia

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Abstract

This research examines the dynamics of 3-dimensional flow and the placement of floating cages in the Semak Daun Lagoon (SDL). The research was carried out using 3-dimensional current modeling process, which is designed in four tidal conditions model in accordance with the wind and tidal pressure generation. Furthermore, this research used the discretization method to vertically determine the finite volume and sigma coordinates, therefore, the whole domain was 43,575 triangular elements. The acuration of model showed by a MAPE value of 9.9%, its shows model is a very good category. The results of the model showed that the monsoons do not have a significant effect on the current pattern and velocity in SDL, however, the dominant current dynamics are influenced by tides.

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In addition, the current pattern in SDL waters generally moves from the Southwest to the Northeast at low tides and vice versa. In all tidal conditions, downwelling and upwelling occurred in the middle of the lagoon, with the current pattern and velocity significantly affected by Bathymetry. Surface and vertical current velocities range from 0.002 - 0.600 m/s. However, the current velocities of 0.10 - 0.20 m/s were only found at -2.3 m depth. Meanwhile, the optimum current velocity for marine cultivation activities is 0.20 - 0.50 m/s, therefore the utilization of SDL waters for floating net cage system cultivation is more optimal at a depth of -2.3 m.

Keywords: 3D current model; cultivation placement; floating net cage system; SDL.

1. Introduction

A lagoon is commonly divided into coastal and atoll lagoons (offshore). It is commonly divided into coastal and atoll lagoons and occurs on mixed-sand and gravel coastlines. Several studies have been carried out in several places on lagoon interaction with the open sea [1-3], its influence on the length and depth of the canal [4-5], tidal flow variability [6-7], cases of flooded inlet-outlet exposed during spring and neap tides [8-9]. Furthermore, [10,1] determined the spatial and temporal variabilities of water quality parameters, while [11] carried out a research on the dominance of the current generated in the lagoon. Generally, these previous studies stated that tides are the major generation of currents in waters [12]. Semak Daun Lagoon (SDL) is classified as an atoll lagoon where most barrier reefs are exposed and inundated at low and high tides, respectively [13]. This condition causes minimal interaction with the surrounding waters at low tide. Furthermore, there are numerous coral spots in the form of atolls and troughs, and they have the potential to cause changes in the pattern and velocity of currents in the water column. Several previous studies carried out on SDL which is similar to this research include tidal types and dynamics of the SDL surface currents [13], the suitability of grouper cultivation [14], as well as [15] the studies for the suitability of vannamei shrimp cultivation in these waters. However, studies on the suitability of current dynamics on the depth as the size of the cultivation cages have never been carried out. SDL is currently used for cultivation use of the floating net cage system. It was selected as a cultivation area by the surrounding communities due to its relatively easy accessibility, namely the proximity of cultivators to their settlements, comfort in terms of oceanographic studies, including the suitability of water quality. Its things become the basis for the cultivation of floating net cage systems in these waters to date. The cultivation system utilizes floating net cages measuring 3 x 3 x 3 m placed at a depth of ≥ 4 m during the least tide [16]. Furthermore, the ideal current velocity is the range 0.1 to 0.5 m/s [16-17]. It was discovered that at a certain depth, the cultivated organism does not get an ideal supply of current for its growth, considering that several types of demersal fish are nurtured. Therefore, this research focuses on the dynamics of currents on the surface and depth of the cage nets. Based on this, the aim of this study is to examine and evaluate current dynamics for the placement and design of floating cages in SDL. Three-dimensional current modeling was carried out based on four tidal conditions. Therefore, this study is expected to be the basis for the development and utilization of floating net cage cultivation system in SDL.

2. Method

2.1. Time and Place of Research

The data required to develop this model consists of wind, tide, depth, current, and coordinates. Measurements of field data were carried out in SDL Seribu Islands Indonesia for 3 days (25 to 27 July 2018), as shown in Figure 1a. Parameters such as tides, depth, the direction of current and velocity, including the coordinates, were measured directly at the study site. On the contrary, information related to the wind were obtained from the website (www.http//ecmwf.com), and it encompasses a time series, with a frequency of 6 hours realized in 2018. The model was operated for 30 days.

2.2. Model Development

The 3D model is designed based on two motion generators, which consist of wind and tidal pressure. It also considers other parameters such as pressure, gravity, coriolis, and frictional gradients per unit mass [18]. System of equation proposed is based on the Reynolds average Navier-Stokes equation. The domain discretization solutions adopted the finite volume method. Subsequently, it was spatially discretized into elements (Figure 1 and Table 1). The horizontal discretization utilized unstructured mesh (Figure 1b) while the vertical domain applied structured mesh (Figure 1c). The vertical domain discretization used are reported as follows the sigma coordinates were obtained by dividing the five-layer depth. The model validation adopted the MAPE in accordance with the suitability criteria, which is stated as follows MAPE <10% - very good, 10 ≤ MAPE <20% - good, 20 ≤ MAPE <50% - fair, ≥ 50% - not good [20].

Table 1: Design of current dynamics model development in SDL

Item	Unit	Total
Vertical discretization	layer	5
Domains discretization	element	43,575
Element area	m^2	1,000 – 1,000,000
Time step model	second	30

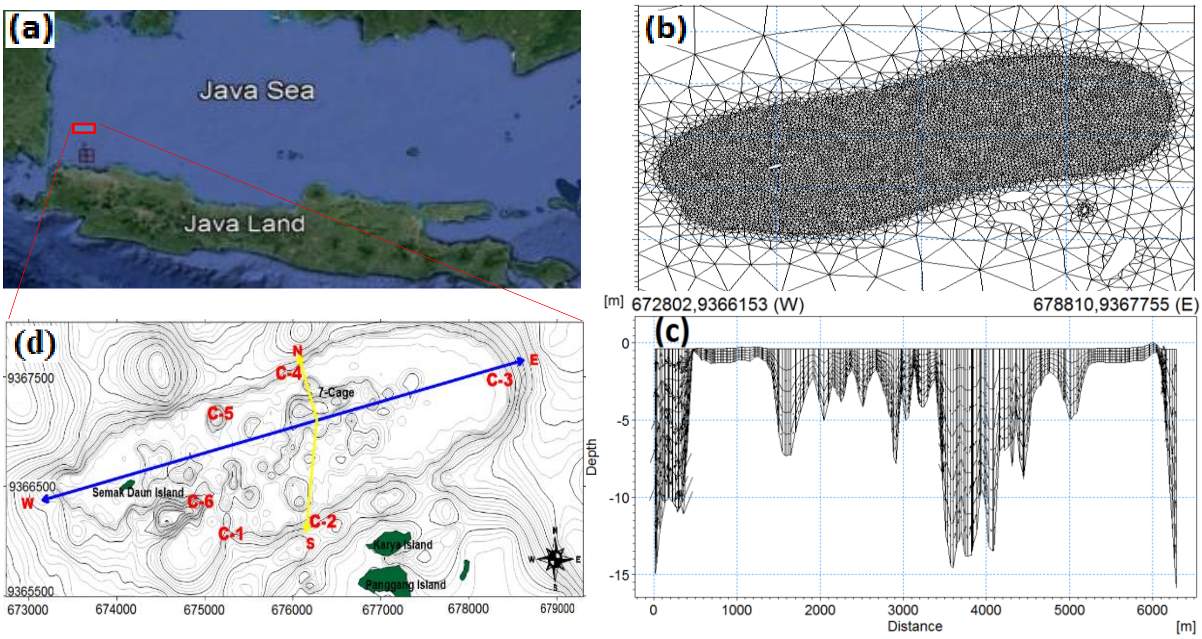

Figure 1: (a) The research location in SDL; (b) horizontal discretization; (c) vertical discretization and (d) depth contours and canals location: the blue line (W-E) is the west-east cross-section, the yellow line (N-S) is the north-south cross-section, C-1 is the southwest canal, C-2 is the south canal, C-3 is the east canal, C-4 is the north canal, C-5 is the northwest canal, C-6 is the west canal and 7-cage is the cage location floating net.

3. Results and Discussion

3.1. Wind, Tidal and Currents

These parameters were observed during the year to determine the relationship between wind velocity and tidal elevation throughout the seasons. The wind analysis showed a velocity within the range of 0.04 to 9.74 m/s, as indicated in table 2. Furthermore, its minimal value was obtained in transition season-2 while its maximum was realized during the west season. In 2018, the tidal level was within the range of -0.33 to 0.52 m, with the minimum and maximum values realized during transition season-1 and western season. Furthermore, the current velocity realized due to the two power stations earlier reported was within the range of 0.002 to 0.075 m/s (7-

Table 2: Wind velocity, tidal elevation and current velocity obtained during different seasons at SDL (7-cage station) in 2018

Item	Season			
	West (Dec - Feb)	Transition-1 (Mar - May)	East (Jun-Augus)	Transition-2 (Sep-Nov)
Wind velocity range (m/s)	0.04 – 9.74 (5.02)	0.27 -8.50 (3.91)	0.19 – 8.18 (3.18)	0.05 – 6.66 (2.88)
Tidal elevation range (m)	-0.36 – 0.52	-0.33 - 0.45	-0.35 - 0.48	-0.37 - 0.45
Current velocity range (m/s)	0.003-0.075 (0.0218)	0.003-0.072 (0.0233)	0.002-0.064 (0.0231)	0.002-0.064 (0.0231)

cage station) with the least value obtained during the East monsoon and 2 transition seasons while its maximum was realized during the West monsoon. The wind velocity is shown in table 2 with the maximum currents and tidal elevations located in the West monsoons. However, the average results from the minimum current velocities were also discovered during the west monsoons with an extremely slight difference. This implies that seasonal changes have no significant effect on current velocity. The results from this analysis show that the use of SDL is independent of the seasons. This is consistent with the studies carried out by [11-12], which stated that tides influence the generation of current dynamics in a dominant lagoon. Based on this, the subsequent analysis is the dynamics of currents in the West monsoon, which is caused by a relatively low velocity in SDL. This is also in accordance with the aim of this study related to current dynamics during the placement of floating net cage systems in which the cultivated organisms requires the appropriate velocity.

3.2. Tidal

The tidal analysis shows that the mixed type occurs on a daily basis, as reported in the research carried out by [13]. The tidal elevation (Figure 2) shows that the tidal valley inside the lagoon is higher than outside the lagoon, as [13] stated that there is a difference in elevation in the north, this causes the sea level inside to be 0.04 m higher than outside. lagoon. This is due to the accumulation of water masses as described [13]. The accumulation causes the movement of water masses or the current speed weak in the lagoon.

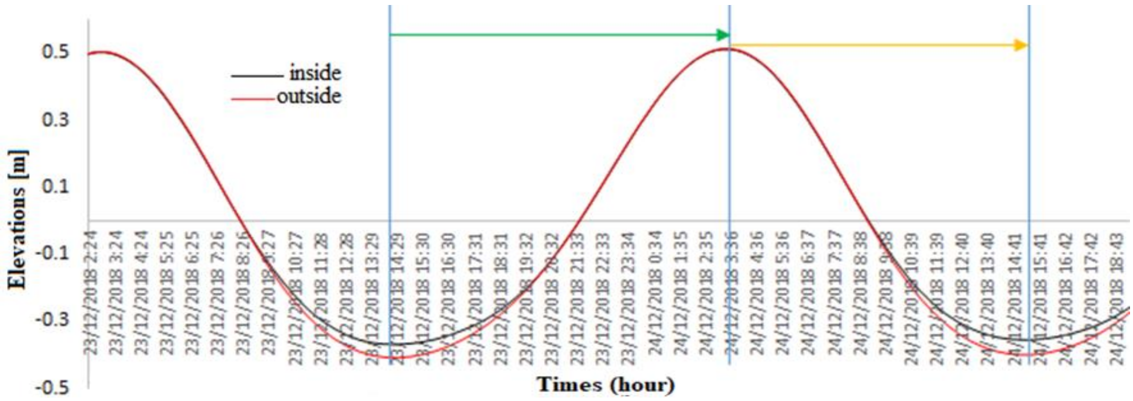

Figure 2: Tidal asymmetry in the model domain, the black line is the tide elevation inside the lagoon, the red line is the tide elevation outside the lagoon, the blue line is the condition of the highest and lowest tides, the green line is the condition towards the tide, the yellow line is the condition towards the low tide.

asymmetry and the time required to attain the maximum and minimum values are 13 hours 8 minutes and 11 hours 1 minute, respectively. Therefore, it takes 2 hours 7 minutes for the longer tide than the lesser one (Figure 2). This time difference also leads to some changes in surface elevation, which was realized to be 0.035 m higher in the lagoon at low tide. According to [13], this is due to the accumulation of water masses, thereby restricting its movement, in other words, the current velocity is extremely weak.

3.3. Currents Dynamics

The results from the current dynamics model are stated at four sea-level elevations, including low tide, low tide towards the tide, tide, and tide towards the low tide. The results realized from the field verification show the suitability of the current characteristics model with a MAPE value of 9.98% (Figure 3). However, this indicates that it was developed according to the field conditions [19].

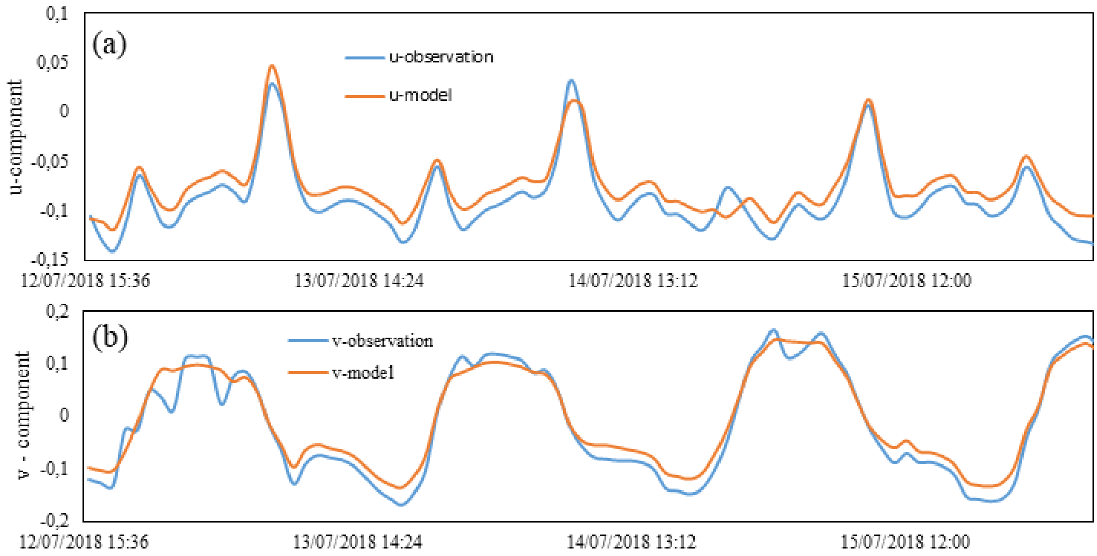

Figure 3: Validation of the current velocity model (a) u-component (b) v-component. The orange line shows the results from the model, while the blue line depicts the field measurements at the location of the floating net cages.

The current surface pattern in Figure 4, shows that the direction of tidal currents is from Northeast to Southwest at low tide and vice versa. This is consistent with the studies carried out by [20,13], which reported that the currents in the area move back and forth following the tidal dynamics. This shows that the generation of currents in SDL is tidal-dominated, this is also consistent with the research carried out by [21] which stated that tidal dynamics influence approximately 70% of the variability of surface elevation and currents in the lagoon and 80% of the movements at the dominant inlet-outlets. At low tide, the current enters through channels C-1 and C-6 and then exits through channels C-2 and C-4. This is due to the exposure of the overall barrier reef in the East. In contrast to the following conditions, namely low and high tides, with the inflow and outflow evenly distributed across the surface of the lagoon in accordance with the direction of the tidal currents. This is caused by barrier reefs that are completely inundated. Based on this, the surface current flows in SDL during the West season is dominant from the Southwest to the Northeast direction and vice versa in the East season. This is consistent with the research carried out by [13], which stated that the surface currents in SDL are dominant from the Northeast to the Southwest during the East Season. Furthermore, the dynamics of surface currents are caused by the West and East monsoons, and its velocity ranges from 0.002 to 0.60 m/s. In addition, the least is found in the four tidal conditions while the maximum value is discovered at low tide near the North canal.

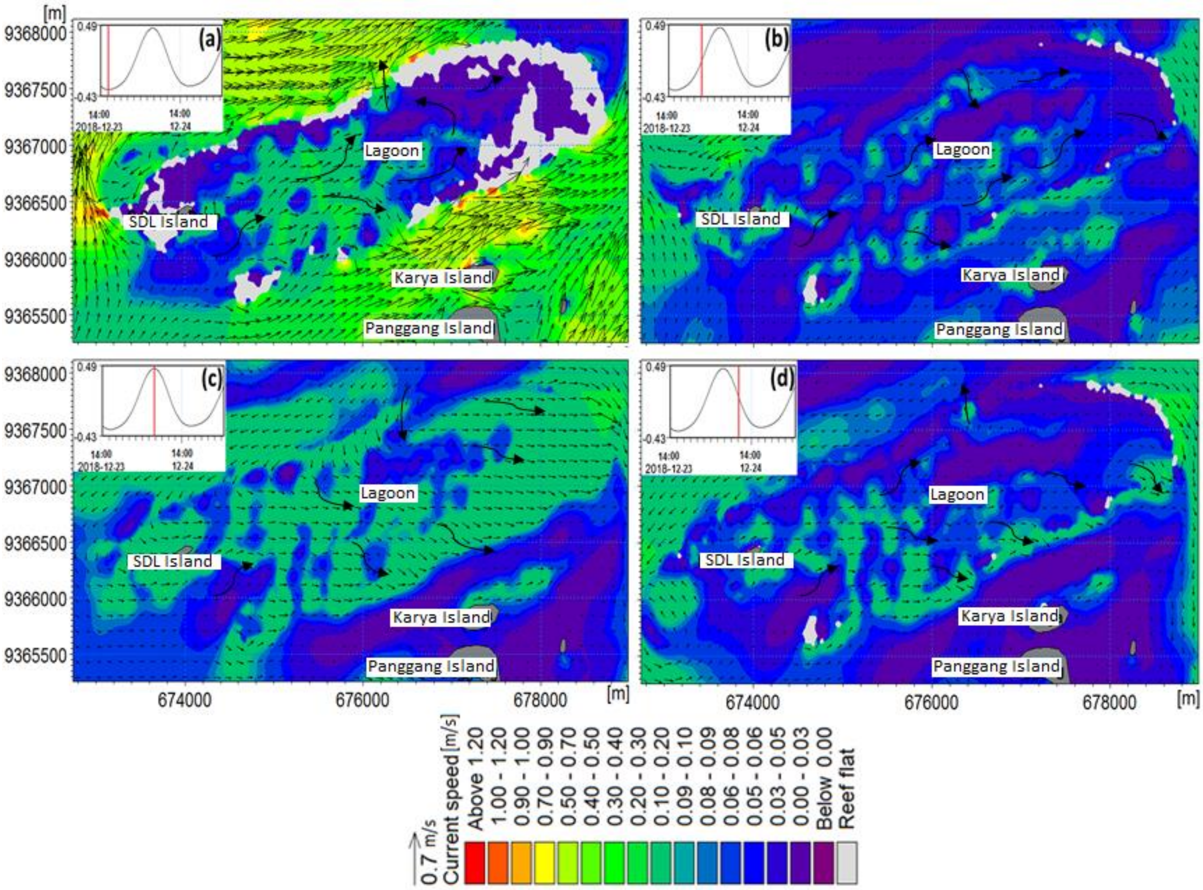

Figure 4: The pattern and velocity of surface currents in SDL during the West monsoon: (a) at low tide, (b) low tide towards tide, (c) tide, and (d) tide towards low tide

Based on the cross-sections of the west (W)-East (E) and north (N)- south (S), at low tide (Figure 5a), the current flows from the West and East to the middle of the lagoon, respectively. This is due to the exposed barrier reefs on the Western and Eastern sides of the lagoon. Therefore, due to this, the water mass tends to down well on the Western and Eastern sides of the lagoon as well as upwell in the center, and is discharged through the Northern canal. In contrast, other tidal conditions (Figs. 5b, 5c, and 5d) shows downwelling and upwelling on the Eastern and Western sides of the lagoon respectively and at low tide towards tide and vice versa. This is because most barrier reefs are inundated at tide towards low tide, low tide towards the tide. On the contrary, they are completely inundated at the tide. In all tidal conditions, some of the water is discharged through the south canal, due to the attraction of its mass towards the eastern part of the lagoon. However, in the southern part of the lagoon, it is pulled discharged through the canal. Furthermore, there is an accumulation of water masses at the center of the lagoon due to narrowing in the northern canal, thereby causing the water in the southern part to easily exit through its canal. The cross-sectional view of W-E and N-S shows that the current velocity from the surface to the near bottom ranges between 0.002 to 0.60 m/s while from 0.10 to 0.20 m/s was only discovered at a depth of -2 m (in conditions of towards tide, tide, and towards low tide). Meanwhile, the depth of the trench was approximately 15.9 m at mean sea level conditions [13], this shows that the current velocity at a depth of -3 m which is at the

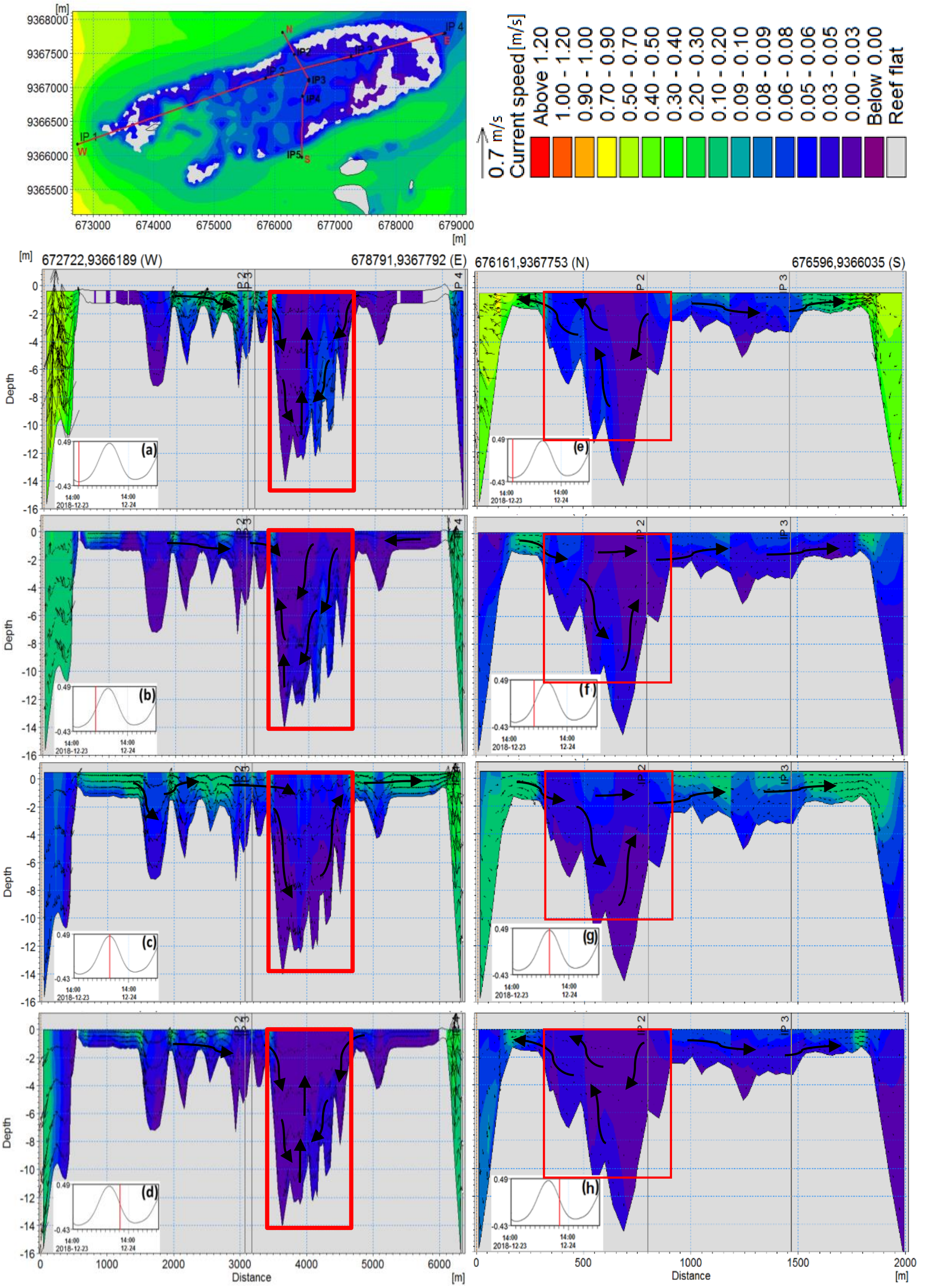

Figure 5: Current patterns and velocities appear across the west-east (W-E) conditions: (a) low tide, (b) low tide towards tide, (c) tide, (d) tide towards low tide. Transverse view of North-South (N-S) is in (a) low tide, (b) low tide towards tide, (c) tide, (d) tide towards low tide in SDL (from 23 to 24 December 2018)

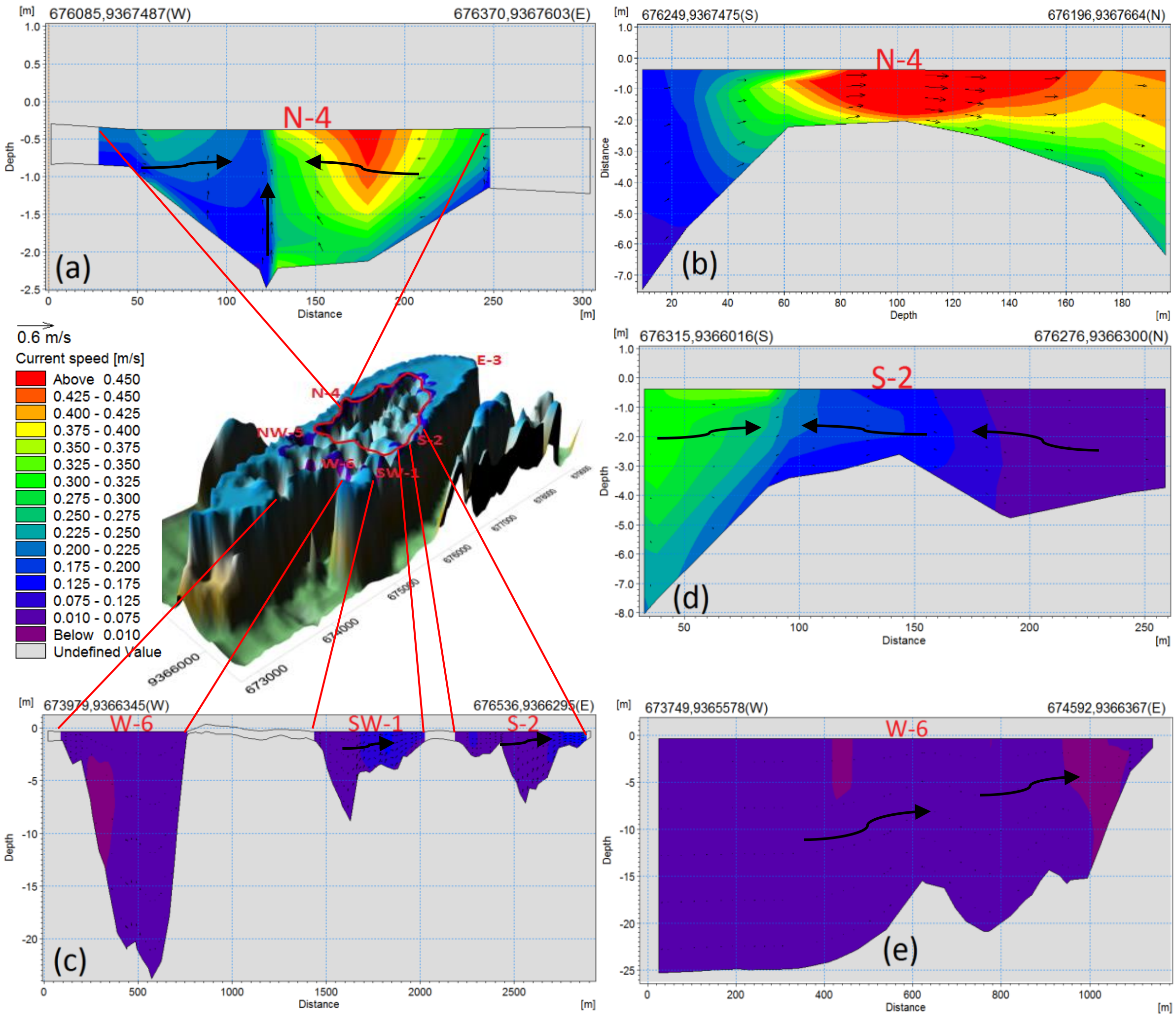

Figure 6: (a) Cross-section (W-E) of the north canal (N-4); (b) South-north cross-section of the north canal (N-4); (c) North-south cross-section of the west canal (W-6), west-east cross-section of the southwest canal (SW-1), west-east cross-section of the south canal (S-2); (d) South-north cross-section of the south canal (S-2); (e) West-east cross-section of the west canal (W-6).

near bottom is less than 0.10 m/s. This proves that the upwelling current is presumed to be unable to lift the base material (resuspend), as reported in the research carried out by [22] which stated that the effectiveness of the resuspension occurs at a current velocity of 1 m/s. At low tide, the northern, eastern, and most southern barrier reefs are exposed (Figure 4a) therefor the Northern canal is the primary channel by which water mass, flows out of the lagoon. In this condition, the wet area of the north canal was narrowed, as shown in Figure 6a, thereby causing the water level to be 0.03 m higher [13]. The consequence implies that there is excess volume due to differences in the elevation, which is approximately 136,755.21 m3 to acquire an elevation balance. Conversely, the flow of water mass entering through the western canal is continued despite being at a relatively low velocity of 0.01 m/s (Figure 6c). This causes the current velocity in the northern canal to increase to 0.60 m/s (Figure 6a and 6b), and it was recorded as the maximum rate in all the areas under the various tidal conditions. The least velocity was discovered at the center of the lagoon near the bottom of the trough, relatively 0.002 m/s at low tide (Figure 5). This is consistent with the research carried out by [11], which stated that low current velocities are often found at the center of the lagoon.

3.4. Current Suitability for Cultivation

The surface and vertical current velocities show that the highest dynamics was found in the area near the northern canal. This indicates that it is ideal for cultivation and has been utilized till date. Furthermore, from the vertical current profile to a depth of 3 m (3 m is the height of the floating net cages) under the four tidal

Table 3: Suitability of current parameters for grouper and vannamei shrimp cultivation

Organism	Current velocity range [m/s]	Score
	0.2 - 0.5	5
	0.1 - 0.19 & 0.51 - 0.75	3
Grouper[1,2,3]	<0.1 & >0.75	1
Vannamei shrimp[4]	0.10 - 0.35	

Source: [17][1]; [16][2]; [23][3]; [15][4]

conditions, the current velocity is inadequate, however at a depth of -2.3 m, it reaches 0.20 m/s (Figure 5). This data shows that the utilization of SDL water columns, particularly in center, is optimal at a depth of -2.3 m. This is based on the quality, standard or suitability of the current velocity (Table 3) in SDL waters.

4. Conclusion

In conclusion, tidal dynamics generally dominate the current pattern in the Semak Daun lagoon. The maximum current velocity was detected near the northern canal at the tide towards low tide condition. On the contrary, its minimum was discovered at the middle and bottom of the lagoon at low tide. Therefore, the northern canal is ideal for cultivation, while the depth of the floating net cages tends to be optimal at a depth of -2.3 m.

5. Recommendation

For cultivators, the optimum depth for the design of the culture cage is -2.3 m. For researchers, it is necessary to study and evaluation the distribution of cultivation waste in the Semak Daun lagoon.

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References

[1]. M. Gacic, M.I. Mancero, V. Kovacevic, A. Mazzoldi, V. Cardin, F. Arena., G. Gelsi. “Temporal variations of water flow between the Venetian lagoon and the open sea”. *Journal of Geophysical Research*, vo. 108, pp. 1-14, 2004.

[2]. D.G. Aubrey, T.R. McSherry, P.P. Eliet. “Effects of multiple inlet morphology on tidal exchange: Waquoit Bay, Massachusetts”. *Coastal and Estuarine Studies*, vol. 44(8), pp. 213-235, 2011.

[3]. M.S.M. Orescanin. “Hydrodynamics of a multiple tidal inlet system: Katama Bay, Marthas Vineyard” Doctoral Philosophy, M.S. University of Illinois, Urbana Champaign, 2015.

[4]. F. Phleger. *Foraminiferal and ecological processes in St Lucia lagoon.* Zululand. Marit Sediments Specific Publication, 1976

[5]. T.M. Hume, C.E. Herdendorf. “Factors controlling tidal inlet characteristics on low drift coasts”. *Journal Coast Research*, 1992.

[6]. L.T. David, B. Kjerfve. Tides and currents in a two-inlet coastal lagoon: Laguna de Te´rminos, Mexico. *Continental Shelf Research*, Vol. 18, pp. 1057-1079, 1998.

[7]. M.C. Sousa, J.M. Dias. “Hydrodynamic model calibration for a mesotidal lagoon: the Case of Ria de Aveiro. J. Coast Res”. *Proceedings of the 9th International Coastal Symposium*, 2007, pp. 1075–1080.

[8]. P.E. Haines, R.B. Tomlinson, B.G. Thom B.G. “Morphometric assessment of intermittently open/closed coastal lagoons in New South Wales, Australia. Estuarine”. *Coast Shelf Scientific*, vol. 67, pp. 321-332, 2006.

[9]. B.D. Morris, I.L. Turner. “Morphodynamics of intermittently open-closed coastal lagoon entrances: New insights and a conceptual model”. *Marine Geological*, vol. 271, pp. 55–66, 2010

[10]. S.R. Pal, P.K. Mohanty. “Use of IRS-1B data for change detection in water quality and vegetation of Chilka Lagoon, East Coast of India”. *International Journal Remote Sens*, vol. 23(6), pp. 1027–1042, 2002.

[11]. A. Contreras, R. Esparza, P. Douillet, H.J. Zavala. “Tidal dynamics of the Terminos Lagoon, Mexico: observations and 3D numerical modelling”. *Ocean Dynamics*, vol. 64, pp. 1349–1371. 2014.

[12]. S. Mitchell, I. Boateng, F. Couceiro. “Ocean & Coastal Management In fl uence of flushing and other characteristics of coastal lagoons using data from Ghana”. *Ocean Coast Management*. Vo. Xxx, pp. 1–12, 2016.

[13]. Saenuddin, I W. Nurjaya, D.G. Bengen, T. Prartono, I. Effendi. “Hydrodynamics modeling with MIKE

system in the Semak Daun Lagoon, Seribu Islands Indonesia". *IOP Conf. Ser.: Earth Environ,* 2020, pp. 1-9. doi:10.1088/1755-1315/429/1/012010.

[14]. Mansur. "Management of Semak Daun Island Water based on environmental carrying capacity in an effort to conserve of coral reef ecosystems (Case Study: Water of Island Semak Daun, Seribu Islands, Indonesia." Magister Science, IPB University, Bogor-Indonesia, 2014. (in Indonesia)

[15]. I. Effendi, M.A. Suprayudi, I W. Nurjaya, E. Harris, Surawidja, E. Supriyono, M.Z. Junior, Sukenda. "Oceanography and water quality condition in several waters of Thousand Islands and its suitability for white shrimp *Litopenaeus vannamei* culture." *Journal of Tropical Marine Science and Technology*, vol. 8 (1), pp. 403-417, 2016. (in Indonesian).

[16]. I. Effendi. Introduction to aquaculture. Jakarta-Indonesia, Penebar Swadaya, 20042004. (in Indonesia)

[17]. M.G.H. Kordi. *Grouper fish hatchery*. Indonesia: PT Perca, 2008, pp 64. [in Indonesian].

[18]. H.G. Ramming, Z. Kwalik. Numerical modelling of marine hydrodynamics. Applications to Dynamic Physical Processes. New York: Elsevier Oceanography Series-Elsevier Scientific Publishing Company, 1980.

[19]. J.J.M. Moreno. "Using the R-MAPE index as a resistant measure of forecast accuracy". *Psicothema,* vol. 25(4), pp. 500-506, 2013.

[20]. H. Surbakti, S.B. Agus. Oceanographic dynamics as a key component in a conservation strategy for an ecosystem-based management formula. National (Indonesia) Ocean Conference (KONAS) IX, 2014, (in Indonesian).

[21]. A.C.R. Esparza, P. Douillet, J.Z. Hidalgo. "Tidal dynamics of the Terminos lagoon, Mexico: observations and 3D numerical modelling". *Ocean Dynamics*, vol. 64, pp. 1349–1371, doi:10.1007/s10236-014-0752-3, 2014.

[22] T. Prartono, T. Hsena. "Kinetic study of phosphorus and nitrogen compounds from sediment resuspension". *Journal of Tropical Marine Science and Technology*. Vo. 1(1), pp. 1-8, 2009. (in Indonesia).

[23]. S Adibrata, M.M. Kamal, F. Yulianda. "Environmental carrying capacity for grouper cultivation (family serranidae) in the waters of the island of pongok, southern bangka district". *Journal of Coastal and Small Islands*, vol. 2(1), pp. 43-58, 2013. (in Indonesia)