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Dissolved Oxygen Availability on Traditional Pond Using Silvofishery Pattern in Mahakam Delta

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Abstract *- The development of aquaculture system should meet the community's basic need economically by taking into account the carrying capacity and environmental sustainability. The development of the environmentally friendly system such as silvofishery is being promoted by government however its yield has not reached the target yet. Dissolved oxygen availability is an important indicator which determines the success of the aquaculture system. The objective of the research was to determine dissolved oxygen availability on traditional pond systems using silvofishery pattern. Time series data collection was conducted once in 14 days with 2 measuring times; in the morning (06.00 am) and in the evening (06.00 pm) for 112 days. The research was conducted at four different silvofishery pond patterns, Pond Pattern 1 (0% mangrove canopy covered), Pond Pattern 2 (35% mangrove canopy covered), Pond Pattern 3 (67% mangrove canopy covered), and Pond Pattern 4 (75% mangrove canopy covered). Measurement was observed openly in the pond (in situ) with parameters: dissolved oxygen, temperature, Water pH, Salinity, Transparency, Wind Speed, and Depth of Water Table, while chlorofil-a was ex-situ measured. The result from each parameter was compared to optimum concentration rate for shrimp growth. From the experiment, Pond Pattern 1 showed the most satisfaction results. Its dissolved oxygen availability during the research was ≥ 4 mg/L which was 5.88 mg/L ±0.48 mg/L in the evening (06.00 pm) and 4.33 mg/L ±1.24 mg/L in the morning (06.00 am). It was also supported by optimum condition of other parameters such as temperature, Water pH, Salinity, Wind Speed, and Depth of Water Table. However, it was not supported by fertility and transparency of water. Thus, the traditional pattern of conservation still needs additional technology to maintain adequate dissolved oxygen availability for optimum shrimp growth.*

Keywords — *silvofishery; ponds; mangrove; dissolved oxygen*

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I. Introduction

Sees delta or estuary from three aspects, which are the composition of fauna, estuary vegetation, and estuary planktons. Estuary is defined as an area of semi-enclosed coastal water body which is directly related to the open sea, profoundly affected by the movement of tide which is mixed with fresh water from inland water discharge (Clark, 1974). Most of the completeness of main physics and biology aspects are not the transition characteristics, but unique nevertheless (Wibowo *et al*., 1996).

Coastal area is a region full of very high pressure caused by human activity as well as the pressure exerted by nature (nature pressure). This condition makes coastal as a region that is vulnerable to a variety of damage which eventually makes it easily degraded. Generally, the damage that often befalls on the coastal region, especially coastal line, caused more to human behavior ignoring the concept of sustainable management in the utilization of coastal region as the source for living. One of the indicators is the depletion of mangrove forest thickness along the coastline as the form of land conversion (Birkmose, 2001).

Mangrove ecosystem is the ecosystem that is adaptive to critical conditions such as high salinity, extreme tides, strong wind, high temperature, muddy substrate, and anaerobic condition (Woodroffe *et al*., 1987; Mfilinge *et al*., 2005). Mangrove is the most productive ecosystem in the world. Mangrove produces commercial products, protect the coast, and support coastal fisheries (Kathiresan and Bingham, 2001).

The greater benefits provided by mangrove ecosystem, the greater the threats will be received. Thus, the silvofishery approach is needed in its management. Silvofishery is a form of brakish water fishery combined with mangrove planting in the same area.

In accommodating the needs of land and employment, mangrove can be managed using silvofishery model associated with beach or coastal rehabilitation program. Silvofishery activity such as constructing ditches in the mangrove area (Quarto, 1999).

Mangrove ecosystem for fishery resources and environment sustainability can be used as a form of silvofishery system, a traditional pond technology combining fisheries with mangrove planting, followed by introduction concept of management system by minimizing input and reducing environmental impact (Macintosh *et al.*, 2002).

According to Fitzgerald and William (2002), the application of silvofishery system must be based on appropriate reason, its basic principle is development continuity and management which should be the major consideration in the development, for example the acceptance and impact of the presence of natural population to the cultivated species must be accepted. It includes the seeds existence and survival rates. The development of silvofishery should be implemented based on specific environmental condition and adjusted to environment carrying capacity. The development should fulfill the community's basic needs economically by taking into account the environmental sustainability. Integrated approach will provide the opportunity to economic activity and still applying conservation and rehabilitation program to mangrove ecosystem.

Silvofishery developed in Indonesia has several models/types, such as ditch or better known as intercropping pond. This pattern is a common silvofishery model that is developed by creating channel for cultivating/raising fish or shrimp. This channel is built surrounding the area used for silvofishery, while mangrove is planted in the center so that there will be a combination between mangrove and fish farming (Fitzgerald, 1997).

This condition could be applied on the abandoned pond area which will be rehabilitated by using pond yard (in the center of the pond) to be planted with mangrove, while the ditch is left untouched. By using this ditch system, the land will be reforested up to 80% of pond area.

The quality of aquatic environment especially in the coastal area is primarily biophysics-chemist factor that can affect the life of aquatic organisms in the ecosystem. Ideal aquatic condition occurs when it can support the organisms to complete their life cycles (Santiago *et al.*, 1987). According to Boyd (1982), the quality of aquatic environment is a feasibility of an aquatic environment to support the life and growth of aquatic organisms and the value is expressed in a certain range.

The range size of measured parameters depends on some factors such as dilution water volume, toxicity/pollutant intensity, climate, depth, stream flow, and topography, resulting in a process of change through the interaction among physical, chemical, biological characteristics. When a factor is interrupted or changed, it will impact the aquatic ecological system. The objective of the research was to observe mangrove contribution to dissolved oxygen availability using silvofishery system on traditional ponds.

II. Materials and Methods

The research took place on a pond unit of fish farming areas in northern side of Mahakam Delta. It is located in Salo Palai village, Kutai Kertanegara regency. There are a pattern pond observed in the research, ponds pattern one with 0% canopy cover, pond pattern two with 35% canopy cover, pons pattern three with 67% canopy cover and ponds pattern four with 75% (Figure 1). The measurement of water quality was carried out both in-situ and ex-situ (Integrated Analysis Laboratory, Fisheries and Marine Science Faculty Mulawarman University). The research was conducted for 4 months (120 days).

Materials used were mangrove, urea fertilizer, SP3 fertilizer, saponin, pond water, Secchi disc, wind. Tools used were measurement equipment for measuring dissolved oxygen and temperature using dissolved oxygen meter type Az 8401 DO meter probe (Az Instrument Corp, Taiwan (R.O.C.), measuring tools of Water pH using pH meter Az 9661 pH meter probe Az Instrument Corp, Taiwan (R.O.C.), salinity measuring equipment using Atago salin handrefractometer (Atago, Japan), sample bottles with 500 ml volume, stopwatch, chlofofil-a measuring unit according to Yosiaki, Haruo, and Sho (1988) using Spectrumlab 22 pc Spectrophotometer (Spectrumlab, Taiwan), measurement of water transparency using Secchi disc and measurement of wind speed using anemometer Luthron (Taiwan).

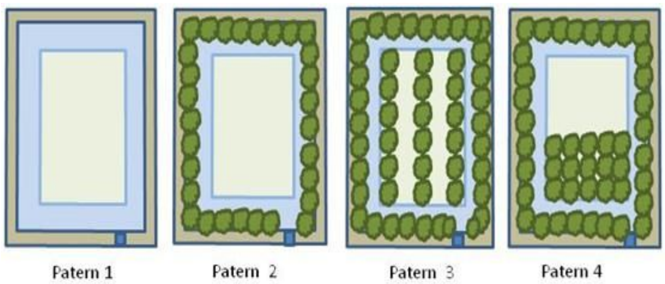


Figure 1. Illustration model of silvofishery pond in the research

The research was divided into three stages; preparation, primary research, and data processing. The primary research was carried out through in-situ and ex-situ measurement. In-situ measurement or directly in the pond consists of dissolved oxygen, temperature, Water pH, Salinity, Transparency, Wind Speed, and Depth of Water Table, while ex-situ measurement consists of measurement of chlorofil-a in Integrated Analysis Laboratory, Fisheries and Marine Science Faculty Mulawarman University. Water sample for ex-situ measurement was preserved by cooling it to $4^{0}C \pm 2\ ^{0}C$. The preservation was conducted to prevent the change of sample water quality caused by the change of sample environment.

Data collection. Time series data collection was conducted once in 14 days for 112 days. The availability of dissolved oxygen, temperature, Water pH, Salinity, Wind Speed, and Depth of Water Table was measured in the morning (06.00 am) and in the evening (06.00 pm), while transparency was directly observed in the afternoon (12.00 pm) and at the same time, the measurement of chlorofil-a was carried out using sample bottle in the surface of water column.

The data then will be processed and converted into matrix. Data from each parameter was then compared with the optimum concentration value for shrimp growth (Table 1).

Table 1. Optimum Pond Water Quality for Tiger Shrimp Growth (Peaneus Monodon Fab)

Criteria	Unit	Optimum	References
Dissolved Oxygen	mg/L	≥ 4	Janssen *et al.*, (1988), Boyd and Zimmermann (2000)
Temperature	^{0}C	23 - 32	Janssen *et al.*, (1988), Boyd and Zimmermann (2000)
Salinity	‰	15 - 25	Poernomo (1988)
Chlorofil-a	mg/L	1 - 3	Jorgensen (1990)
Wind	$m.s^{-1}$	< 1,667	Hutabarat and Evans (2008)
Water pH	-	6.0 – 8.0	Boyd and Zimmermann (2000)
Transparancy	m	0.20 – 0.30	Hossain *et al.*, (2004)
Depth to Water Table	m	> 1.00	Hajek and Boyd (1993)

III. Results and Discussion

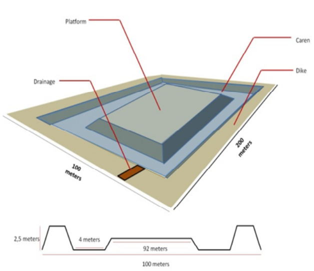
The research took place on a pond unit of fish farming areas in northern side of Mahakam Delta. It is located in Salo Palai village, Kutai Kertanegara regency, East Kalimantan Province, Indonesia. It is located around the equator wih constant high temperature (annual temperature 26–28°C) and minimum annual variation. Moreover, it has minimum annual variation and limited difference of diurnal temperature. Tidal currents are the mixture of diurnal and semi-diurnal components with tidal range about 2.5 m and have very low wave energy. The tides combined with high stream of Mahakam River (1500 m^3/s). Mahakam Delta region is dominated by mangrove ecosystem which covers area at approximately 150.000 ha, made up of a long process of sedimentation from Mahakam River, its length is 770 km water discharge is 1.500 m^3/s and suspended solid material up to 80 mg/l. The high river discharge strongly influences the mangrove vegetation formation in Delta Mahakam.

Delta Mahakam covers an area approximately 1500 km^2 and the distance between the edges of Eurasian plate at about 25 km from the delta land. Mahakam Delta has seasonally-varied fluvial discharge with no significant flood. In general, geological condition of Mahakam Delta is a dynamic region, but on the contrary the main canals are relatively stable. There were 4 units of pond observed in the research, each has the area of 2 ha, with 1 water gate unit which is functioned as the inlet and outlet of water. Illustration model is displayed in Table 2.

Table 2. Silvofishery patterns in the research

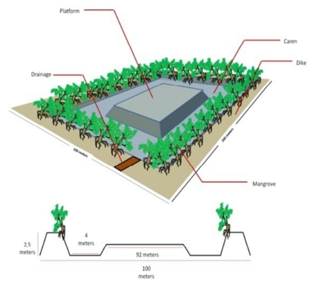
Patern 1

0 % canopy covered



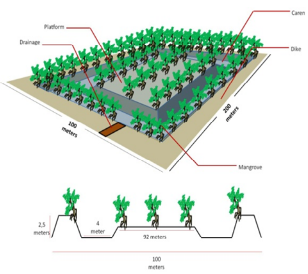
Patern 2

35 % canopy covered



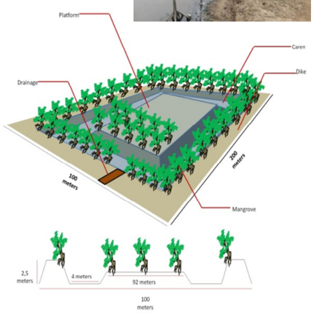
Patern 3

67 % canopy covered



Patern 4

75 % canopy covered



There are two parts in the inside of the ponds: pond yard which embankment is 2 m width, pond area is 16.200 m^2 and caren area is 3800 m^2. All pond units have different models. Pond pattern 1 without mangrove and the other three patterns were planted with mangrove but different in planting models. Mangrove species used was *Rhizophora mucronata*, plant spacing was 1.5 m in a lane.

Production management used in the entire observed models was traditional system commonly used by the fish farmers. The details of production process management are listed below Table 3.

Dissolved oxygen availability is the presence of the dissolved oxygen in a given time. Shrimp will optimally grow when dissolved oxygen concentration is ≥ 4 mg/L (Janssen *et al.*, 1988; Boyd and Zimmermann (2000). The measurement of dissolved oxygen that has been conducted on the whole pond models are displayed in Table 4.

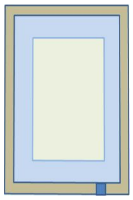
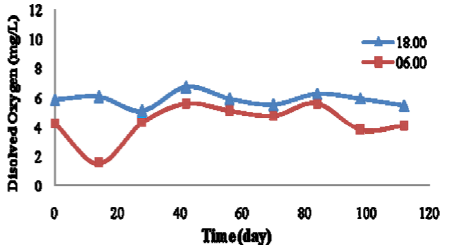
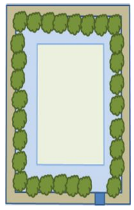
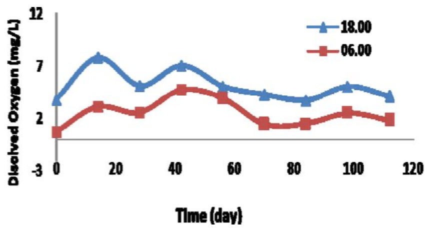
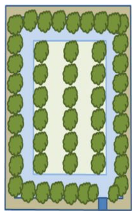
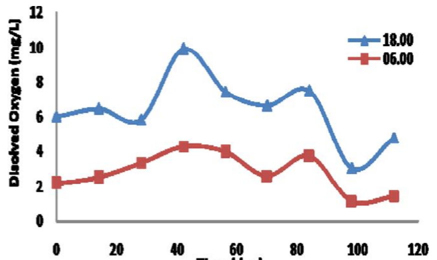
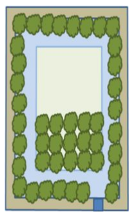
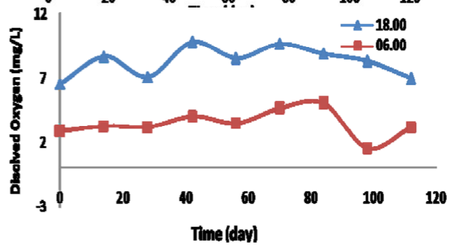
Table 3. The activity of aquaculture by fish farmers

Activity	Criteria	Description
Basic Land Management of Pond		
Drying soil	-	
Mud removal	+	Mud removal is only done in caren and placed on the dike
Addition of Lime	-	
Addition of Fertilizer	+	150 kg TSP fertilizer
Pest and Disease Extermination		
Pest Extermination	+	Using 40 kg of saponin, immersed overnight before apply in the field.
Disease Prevention	-	
Water Quality Management		
Water Quality Monitoring	-	
Treatment	-	
Addition of Extra Fertilizer	-	
Seed Management		
Selection of Seed	-	
Adaptation	+	A container of milk fish fry is soaked in the pond for 30 minutes, and then the pond water is gradually added and spread in the pond.
Feeding Management		
Natural Feeding	+	Natural feed that grows naturally in the pond water
Artificial Feeding	-	
Monitoring		
Shrimp Development	+	Visual observation
Irrigation System		
Enclosed	-	
Semi-enclosed	+	Water inlet occurs every high tide
Open	-	

(+) = conducted, (-) = not conducted

The results of measurements of dissolved oxygen in Pond Pattern 1 in the evening (06.00 pm) showed that the average dissolved oxygen (± SD) was 5.88 mg/L ± 0.48 mg/L and the average dissolved oxygen (± SD) in the morning (06.00 am) was 4.33 mg/L ±1.24 mg/L, while in Pond Pattern 2 the average dissolved oxygen in the evening at 06.00 pm (± SD) was 5.12 mg/L ± 1.42 mg/L and the average dissolved oxygen (± SD) in the morning (06.00 am) was 2.50 mg/L ±1.28 mg/L. Furthermore, the measurements of dissolved oxygen in Pond Pattern 3 in the evening (06.00 pm) showed the average dissolved oxygen (± SD) was 6.42 mg/L ± 1.91mg/L and the average dissolved oxygen (± SD) in the morning (06.00 am) was 2.81 mg/L ± 1.10 mg/L, while in Pond Pattern 4 when the average dissolved oxygen was measured in the evening (06.00 pm) showed the result (± SD) was 8.30 mg/L ± 1.16 mg/L and in the morning (06.00 am) (± SD) was 3.52 mg/L ± 1.28 mg/L. The pond pattern which showed the highest concentration of dissolved oxygen was Pond Pattern 1 because its average concentration both in the morning and evening were ≥ 4 mg/L.

Table 4. The results of dissolved oxygen measurement on the whole Silvofishery pond model patterns

Pond Pattern	Dissolved Oxygen Measurement Chart (mg/L) for 112 days
Patern 1 	
Patern 2 	
Patern 3 	
Patern 4 	

Dissolved oxygen saturation greatly influences the availability of dissolved oxygen in water column. Dissolved oxygen saturation in sea water depends on the presence of oxygen, temperature, and salinity (Jeffries and Mill, 1996). Saturation level of dissolved oxygen on the whole pond models is displayed in Table 5. This research using standard for dissolved oxygen saturation in air pressure 760 mmHg (Richard and Corwin (1956) *in* Weber (1991). The results of measurements and calculations of dissolved oxygen saturation on the whole pond patterns showed only Pond Pattern 3 (in the evening) that already in the state of supersaturated or saturation level >100%. Supersaturated dissolved oxygen on Pond Pattern 3 means the production of dissolved oxygen will be released to the air until it reaches the maximum limit of saturation which is 100% or 6.9 mg/L, while the other pond patterns still have the opportunity to increase the concentration of dissolved oxygen until the saturation limit is achieved.

Table 5. Dissolved oxygen saturation status and its association with the presence of temperature and salinity

Location	Average of Result In situ Measurements				Dissolved Oxygen Saturation (mg/L) *	Saturation (%)	Status
	Time	Temperature (^{0}C)	Salinity (%)	Dissolved Oxygen (mg/L)			
Pattern 1	06.00 pm	31.12	19.68	5.88	6.9	85.21	Unsaturated
	06.00 am	29.17	19.68	4.33	7.2	60.13	Unsaturated
Pattern 2	06.00 pm	30.67	18.54	5.12	6.9	74.2	Unsaturated
	06.00 am	29.4	18.54	2.5	7.2	34.72	Unsaturated
Pattern 3	06.00 pm	31.32	1861	8.3	6.9	120.29	Super saturated
	06.00 am	28.55	18.61	3.52	7.2	48.88	Unsaturated
Pattern 4	06.00 pm	31.33	18.6	6.42	6.9	93.04	Unsaturated
	06.00 am	29.52	18.6	2.81	7.2	39.02	Unsaturated

Chlorophyl-a is an essential component in the production of oxygen, its presence is really needed in the process of photosynthesis. The result of measurements that had been taken during the experiment on Pond Pattern 1 is displayed bellow (Figure 2).

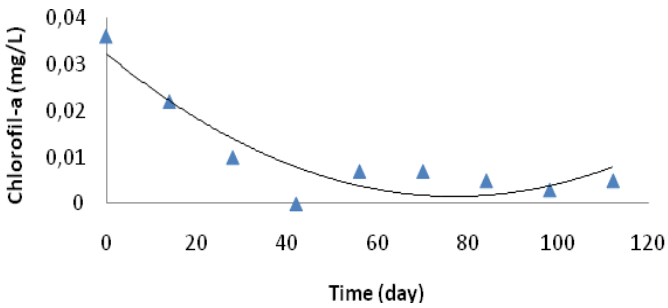


Figure 2. The amount of chlorophyl-a for 112 days on Pond Pattern 1

The results of measurements on Pond Pattern 1 showed that the initial amount of chlorophyll-a was 0.036 mg/L, subsequently continued to decline until it reached 0 mg/L on day 42, but then increased again to 0.007 mg/L on day 56. It was then relatively stable until the last day of the experiment which was 0.005 mg/L. The average amount of chlorophyll on Pond Pattern 1 was 0.011 mg/L ± 0,011, that amount of chlorophyll means the fertility of pond water was categorized as oligotrophic or lacking in fertility because the amount of chlorophyll-a was < 1 mg/L (Jorgensen, 1990).

The result of measurements that had been taken during the experiment in Pond Pattern 2 is displayed bellow Figure 3.

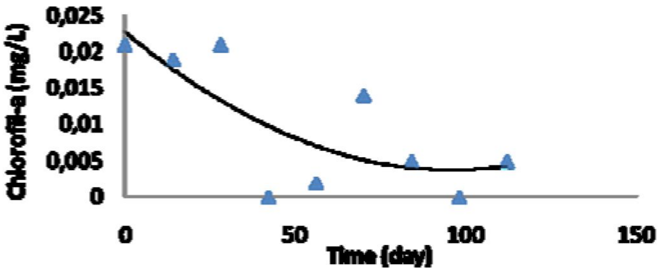


Figure 3. The amount of chlorophyl-a for 112 days on Pond Pattern 2

The result of measurements on Pond Pattern 2 showed that the initial amount of chlorophyll-a was 0.021 mg/L until day 28, subsequently continued to decline until it reached 0 mg/L on day 42, but then increased again to 0.014 mg/L on day 70. It was then relatively stable until the last day of the experiment which was 0.005 mg/L. The average amount of chlorophyll on Pond Pattern 2 was 0.010 mg/L ± 0.009, that amount of chlorophyll means the fertility of pond water was categorized as oligotrophic or lacking in fertility because the amount of chlorophyll-a was < 1 mg/L (Jorgensen, 1990).

The result of measurements on Pond Pattern 3 (Figure 4) showed that the initial amount of chlorophyll-a was 0.012 mg/L and it increased to 0.017 mg/L on day 14, then decline until it reached 0.002 mg/L on day 28, but then increased again to 0.06 mg/L on day 42. The amount of chlorophyll in the next day continued to decline until the last day of experiment which was 0.002 mg/L. The average amount of chlorophyll on Pond Pattern 3 was 0,014 mg/L ± 0.018, that amount of chlorophyll means the fertility of pond water was categorized as oligotrophic or lacking in fertility because the amount of chlorophyll-a was < 1 mg/L (Jorgensen, 1990).

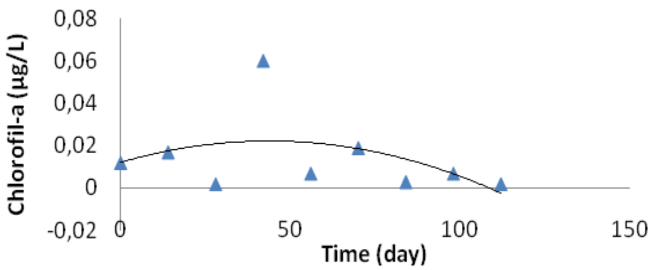


Figure 4. The amount of chlorophyl-a for 112 days on Pond Pattern 3

Furthermore, the measurement of chlorophyll-a on Pond Pattern 4 (Figure 5) was really fluctuatif from the beginning to the last day. It can be seen as the initial amount of chlorophyll-a was 0.012 mg/L and increased to 0.012 mg/L then decline to 0.002 on day 14. However, it rose again on day 70 which was 0.021 mg/L and 0.06 mg/L on day 70. The amount of chlorophyll was declined in the next days until the last day of the experiment which was 0.015 mg/L. The average amount of chlorophyll was

0.009 mg/L ± 0.008. It was categorized as oligotrophic or lacking in fertility because the amount of chlorophyll-a was <1 mg/L (Jorgensen, 1990).

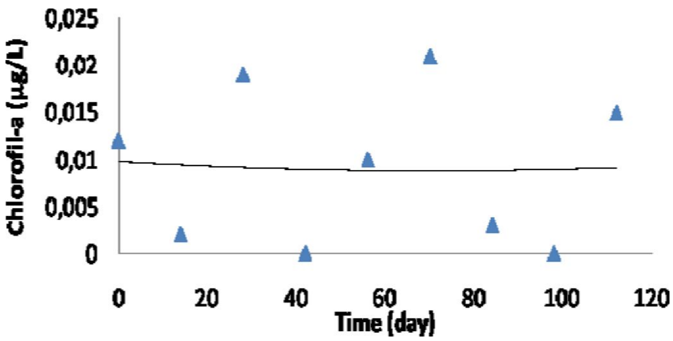


Figure 5. The amount of chlorophyl-a for 112 days on Pond Pattern 4.

The pond pattern which had the highest average amount of chlorophyll-a was Pond Pattern 4 with the average value 0.014 mg/L ± 0.018. However, all pond patterns were categorized having low fertility.

On the measurement of physical and chemical parameters such as wind speed indicated that the wind speed greatly affected the availability of dissolved oxygen in water, because it can assist to induce oxygen from the air to the water, especially in the water surface. The measurement of average wind speed indicated that Pond Pattern 1 was more exposed to the wind with the highest wind speed was 1.90 ± 1.14, while Pond Pattern 4 showed the lowest result in wind speed which was 0.78 ± 0.69. Mangrove coverage affects in inhibiting the exposure of wind in pond. Wind speed received in all pond pattern was in safe category (Evans and Hutabarat, 2008).

Table 3. The measurement of average wind speed, Water pH, Transparency, and Depth to Water Table in all pond patterns

Criteria	Unit	Pond Pattern					References
		Patern 1	Patern 2	Patern 3	Patern 4	Most Suitable	
Wind Speed	$m.s^{-1}$	1.90 ± 1.14	0.95 ± 0.59	0.78 ± 0.69	1.18 ± 0.91	< 1.66	Hutabarat and Evans (2008)
Water pH	-	7.03 ± 0.48	6.95 ± 0.54	7.41 ± 0.38	7.10 ± 0.48	6.0 - 8.0	Boyd and Zimmermann (2000)
Transparency	m	0.53 ± 0.11	0.61 ± 0.13	0.33 ± 0.10	0.40 ± 0.11	0.20 - 0.3	Hossain *et al.*, (2004)
Depth to Water table	m	1.40 ± 0.15	1.06 ± 0.12	1.27 ± 0.19	1.67 ± 0.26	> 1.0	Hajek and Boyd (1993)

The measurement that had been conducted to the entire pond patterns showed the average water pH is acceptable for fish farming activity because the acidity level was tolerable between 6.0 – 8.0 (Boyd and Zimmermann, 2000). The highest water pH average was on Pond Pattern 3 which was 7.41 ± 0.38 and the lowest was on Pond Pattern 2 which was 6.95 ±0.54. While the measurement of transparency conducted on all pond patterns showed the average water transparency was not feasible because the required transparency was about 0.20–0.30. (Hossain *et al.*, 2004). The highest water transparency average was on Pond Pattern 2 that was 0.61±0.13, while the lowest was on Pond 3 with 0.33±0.10.

The ideal depth to water table is > 1.00 m (Hajek and Boyd, 1993), thus the measurement result on all pond showed the average water depth was feasible for fish farming activity. The highest water depth average was on Pond Pattern 4 and the lowest was on Pond Pattern 2, they were 1.67±0.26 and 1.06±0.12, respectively.

IV. Conclusions

1. The average dissolved oxygen availability on Pond Pattern 1 was ≥ 4 mg/L, it means that it can support the optimum shrimp growth. The average amount of chlorophyll was 0.011 mg/L ± 0.011.
2. The average dissolved oxygen on Pond Pattern 2 was ≥ 4 mg/L only in the evening, while in the morning (06.00 am) the average concentration of dissolved oxygen was ≤ 4 mg/L. This condition cannot support the optimum shrimp growth. The average amount of chlorophyll was 0.010 mg/L ± 0.009.
3. The average dissolved oxygen on Pond Pattern 3 was ≥ 4 mg/L only in the evening, while in the morning (06.00 am) the average concentration of dissolved oxygen was ≤ 4 mg/L. This condition cannot support the optimum shrimp growth. The average amount of chlorophyll was 0.014 mg/L ± 0.018.
4. The average dissolved oxygen on Pond Pattern 3 was ≥ 4 mg/L only in the evening, while in the morning (06.00 am) the average concentration of dissolved oxygen was ≤ 4 mg/L. This condition cannot support the optimum shrimp growth. The average amount of chlorophyll was 0,009 mg/L ± 0.008.
5. The entire pond patterns showed the amount of chlorophyll is categorized as oligotrophic or lacking in fertility because the amount of chlorophyl-a was < 1 mg/L.
6. The conservation pattern still using traditional model. Therefore, the additional support from technology to maintain the dissolved oxygen availability for the optimum shrimp growth is still needed.

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