The relationships between water quality parameters and the growth rate of white shrimp (*Litopenaeus vannamei*) in intensive ponds

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Abstract. The purpose of this study was to determine some relationships between dissolved oxygen fluctuations and water quality parameters, and their effects on shrimp growth rates during intensive aquaculture cycles, using the concept of an *ex-pose facto* causal design or observation based on natural conditions in the field. In addition, the objects of the investigation were 8 intensive ponds withe the size of 3200 m^2, with a density of 110 fry/m^2, using paddle-aerators of 16 HP/pond. The variables observed were the dissolved oxygen, temperature, pH, salinity, measured twice a day (morning and afternoon), and the parameters CO_3^{2-}, HCO_3^-, alkalinity, total ammonia nitrogen (TAN), PO_4^-, total organic matter (TOM), NO_2^-, total Vibrio content (TVC), total bacteria count (TBC) and plankton abundance, measured once a week. To find out the multi-parameter relationship and its effect on shrimp growth, the SPSS ver.16 was used. The results showed that the dynamics of dissolved oxygen fluctuations in water have a negative correlation with temperature, phosphate, nitrite, TAN, TOM, TVC and total bacteria during the operational cycle of shrimp culture. From the water quality parameters that have a close correlation, the dissolved oxygen, nitrite, TOM, and total vibrio (TVC) are parameters that have dynamic fluctuations during the shrimp culture. Nitrite is the parameter of water quality that has the highest influence on the growth rate of shrimp, by 75.2%, compared with dissolved oxygen, TOM, and total vibrio (TVC).
Key Words: dynamics, water quality, *Litopenaeus vannamei*, intensive ponds.

Introduction. Water quality is a very important natural indicator for evaluating the feasibility of shrimp farming (Ma et al 2013; Sahrijanna & Sahabuddin 2014). Dissolved oxygen (DO) is an important abiotic parameter for assessing the quality of water in the intensive aquaculture system of vannamei shrimp (*Litopenaeus vannamei*), which must be measured periodically (Madenjian 1990; Kuligiewicz et al 2015). The optimum average concentration of DO during this process is between 4.4 and 8.6 mg/L (Chakravarty et al 2016), and the solubility is strongly influenced by salinity level and water temperature (Boyd 1998). Therefore, at low solubility intensity, an increase in toxic capacity of ammonia gas is probable, which makes aquatic organisms prone to stress (Sriyasak et al 2015). Generally, the production of DO is determined by the presence of photosynthesis, the use of paddlewheel aerators, air diffusion and water exchange activity (Boyd 1998).

In aquaculture ponds, the DO concentration fluctuates (Rahman et al 2015) and this is strongly avoided by farmers. Therefore, the value decreases in intensive ponds as the shrimp are older (Supriatna et al 2017). This is caused by the rise in decomposition promoted by the existing organic material and nutrient (Avnimelech & Ritvo 2003; Nguyen et al 2007). In addition, the decrease in the amount of DO leads to a slow growth rate and feed conversion ratio of the shrimp (Allan & Maguire 1991), broadly impacting the capability of the cultivation environment (Anongponyoskun et al 2012).

Poor water quality makes the shrimp growth rate decrease and the mortality rate to increase due to fluctuations changes in the ecosystems dynamics (Paez-Osuna et al 2003; Edhy et al 2010; Anand et al 2019). Thus, the purpose of this study is to determine the relationship of DO fluctuations and water quality parameters and their effects on shrimp growth rates during intensive culture cycles.

Material and Method

Description of the study location and experimental design. This research was conducted in Panimbang village, Pandeglang, Banten, from June to September 2015, during one intensive cultivation cycle of vannamei shrimp. The method applied was the *ex-pose facto* causal design, implying the analyses of the study objectives based on existing natural phenomenon conditions in the field, during a 91 day period in this case. 8 ponds with a size of 3200 m^2 and a stocking density of 110 fry/m^2 were used. Paddle-wheels totaling 16 HP/pond were also used, and the pond management followed the CBIB (good aquaculture practices in Indonesia) standards. The quality parameters during cultivation activities, including DO, pH, temperature and salinity, were determined *in situ* every day at 5 A.M. and 12 P.M. Furthermore, TOM, CO_3^{2-}, HCO_3^-, alkalinity, TAN, nitrites, phosphates, plankton abundance, Vibrio bacteria and TBC were measured once a week.

Water quality determination. DO levels were assessed using the DO Meter YSI 550i model, while the pH involved a pH tester by Eutech EC-pH. In addition, the temperature involved the use of a Hg thermometer, while salinity was measured with a MASTER S10@Atago refractometer. Furthermore, the weekly quality parameter determinations were conducted using a water sampler on the surface, middle and bottom parts of the ponds, which were later stored in 250 mL containers. Subsequently, the samples were analyzed at PT Menjangan Mas Nusantara, Pandeglang, following the APHA procedure (1980).

The samples for assessing TBC and Vibrio content were obtained following the weekly water quality sampling, where up to 100 mL were extracted and subsequently analyzed at the microbiology laboratory of PT Menjangan Mas Nusantara. In addition, the TBC was diluted gradually until a 10^{-3} dilution was reached, which was planted in TSA (Tryptic Soy Agar) media. The total Vibrio content was diluted until a 10^{-1} dilution was obtained and successively planted on TCBS (Thiosulfate Citrate Bile Salts) media. Both media were incubated at room temperature for 24 hours and the number of colonies was calculated following morphological characters based on shape, color and size, using the Total Plate Count (TPC) method (Prescott et al 2002).

The samples for plankton abundance were acquired at the same time with the bacterial samplings. It were afterwards poured into 50 mL recipients and subsequently analyzed at the water quality laboratory. The plankton abundance was calculated using the Haemocytometer@NEUBEUR on a light microscope and further calculated based on the following formula (APHA 1980):

$$N=100(PxV)/(0.25xW)$$

Where: N - amount of plankton per liter; P - amount of plankton; V - volume of the plankton sample; W - volume of the collected water sample.

Statistical analysis. The data collected were grouped based on the measurement time and analyzed descriptively, in order to identify the level of DO fluctuations during one shrimp culture cycle. The DO relationship with other quality parameters was determined using a correlation test, by the SPSS software Ver. 16.

Results and Discussion. The fluctuation values of DO concentrations during one cultivation cycle of vannamei shrimp are presented in Figure 1. The lowest concentration point occurred at the cultivation age of 41 days, 4.25 mg/L, while the highest concentration value was observed on the 9th day (7.35 mg/L). Therefore, the decrease could have occurred due to the incidence of post blind feeding. The administration of feed could have been capable of increasing aggregates and effecting a change in DO, which fluctuated following the estimation results of the observations on the feeding tray. Conversely, the DO consumption level increases together with the increase of feed input, because of the biosynthesis of the waste and other organic materials (Duy et al 2008; Mirzaei et al 2019). Hence, it is indicated that a larger amount of feed administered more often leads to greater levels of DO consumption in the waters (Ullman et al 2019). Other reasons for a decrease at certain times include abiotic factors like temperature, pH and water salinity (Boyd 1998; Villarreal et al 1994; Cao et al 2019).

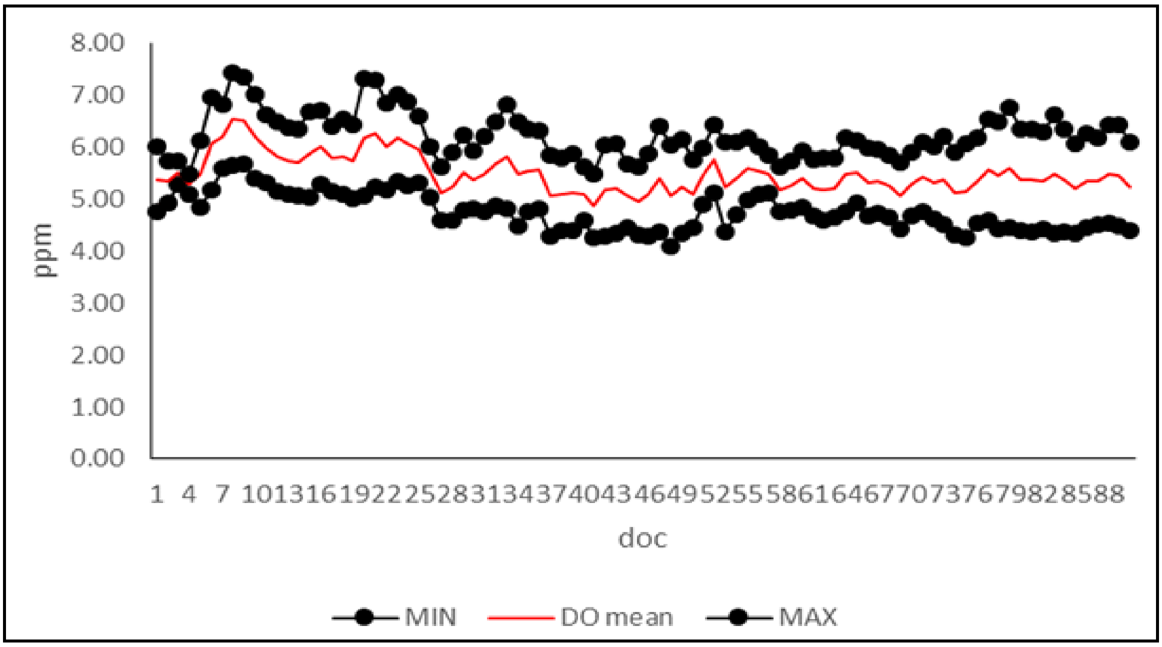

Figure 1. The level of dissolved oxygen fluctuations during the shrimp culture period. MIN – minimum value; DO – dissolved oxygen; MAX – maximum value; doc – days of culture.

The diurnal fluctuations of DO can be observed in Figure 2. The concentration reached the minimum point at 10 P.M. and further increased to its peak at 1 P.M. This shows that an elevated value occurred at night, although no photosynthetic activity was seen because the increase was due to a nocturnal decline in water temperature, which promotes the mechanism of oxygen diffusion from the atmosphere to the water column (Supriatna et al 2017). Meanwhile, the highest point of DO level was recorded in the afternoon (1 P.M.), being the peak time of photosynthesis, which highly promotes oxygen saturation (McGraw et al 2001). Moreover, the fluctuation was also influenced by the use of paddlewheels, organism respiration and the decomposition rate of organic matter by microorganisms (Allen et al 1984; Ruttanagosrigit et al 1991; Li et al 2013). The fluctuations of DO will provide an overall dynamic effect on the pond ecosystem, so it is desirable to always condition the biotic and abiotic factors in the pond to always be stable to maintain the balance of the ecosystem (Edhy et al 2010).

The average concentration of DO is presented in Table 1. The mean DO concentration was 4.71±2.06 mg/L, with the lowest at 3.72 mg/L and the highest value at 8.92 mg/L. In addition, shrimp culture demands maintaining the DO level above 4.5 mg/L (Simbeye & Yang 2014), while the optimum value in vannamei shrimp farming ranges between 4–5 mg/L (Islam et al 2004a), being influenced by the salinity level, shrimp weight and stocking density (Vinatea et al 2011; Boyd & Tucker 1998). This optimum value is highly important in the dynamics of pond water quality and a vital parameter for aerobic respiration and oxidation-reduction process in water and sediment ponds (Boyd 2000). Furthermore, this is also strongly influenced by water exchange, agitation, temperature, salinity, algal growth and the level of decomposition (Abraham & Sasmal 2009). In addition, juvenile shrimp require an optimum DO level of 4.1 mg/L and are unable to survive at 0.65 mg/L (Vinatea et al 2009). Although they are able to tolerate levels of 2 mg/L, stress occurs at lower levels (Kramer 1975). Furthermore, shrimp under this condition tend to experience a decline in growth rate and consequently death (Allan & Maguire 1991; Garcia & Brune 1991).

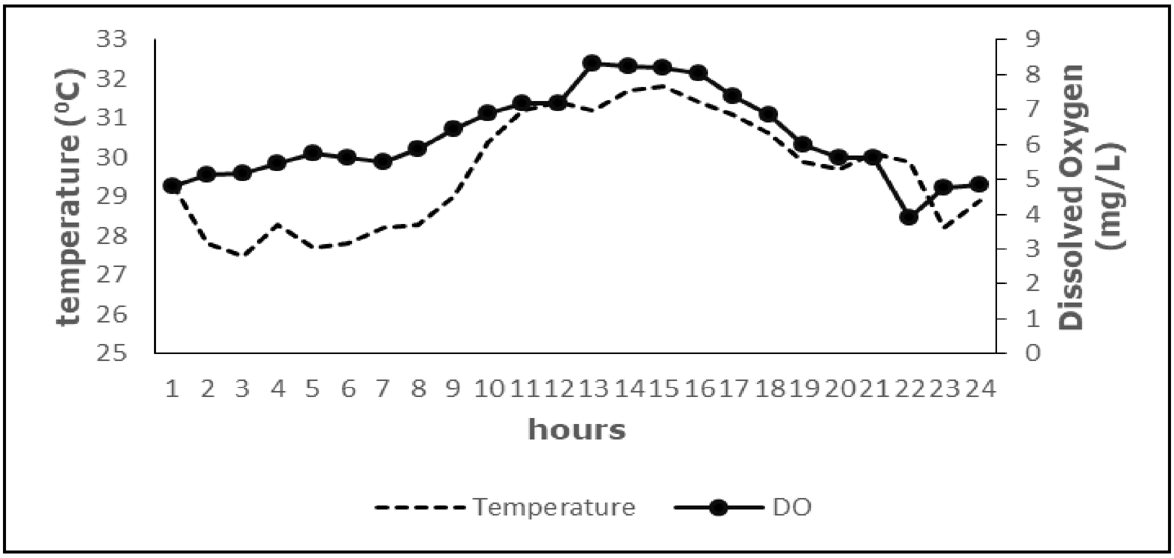

Figure 2. The fluctuations of dissolved oxygen (DO) and temperature during a 24-hour observation period.

Besides respiration, the presence of oxygen in the ponds is also pertinent in the decomposition of organic materials by heterotrophic organisms, as a fundamental process in the aquatic ecosystems (Green & Ward 2011; Passerini et al 2015). This material originates from dead plankton and the accumulation of leftover feed waste (Djumanto et al 2018). Hopkins et al (1991) show that at a DO level of 3 mg/L, 1 HP of waterwheel is able to oxidize the level of feed input by up to 16 kg, while according to Pedersen et al (2019), the decomposition rate has a positive correlation with the level of oxygen demand. Hence, it is highly important to understand the dynamics of the DO level fluctuations as a way of managing optimal cultivation (Culberson & Piedrahita 1996).

Table 1

The concentration of dissolved oxygen during the shrimp culture period

Ponds	*Mean*	*Min*	*Max*
C1	4.83±2.13	4.03	8.92
C2	4.69±2.07	4.02	7.74
C3	4.59±2.02	4.14	8.17
C4	4.66±2.03	4.32	7.57
C5	4.79±2.10	4.04	8.80
C6	4.73±2.06	4.01	7.40
C7	4.84±2.11	4.02	8.42
C8	4.56±1.99	3.72	8.32

Note: Min – minimum value; Max – maximum value.

The data on water quality parameters is presented in Table 2. The daily measurement of pH was carried out, where the average value was 7.8±0.23, with 7.7 recorded in the morning and 8.0 in the afternoon. The water salinity value was 34 ppt, fluctuating daily.

The temperature average value was 27.5^{0}C, where 26.7^{0}C and 28.2^{0}C were recorded in the morning and afternoon, respectively. The concentration of DO had an average value of 4.71 mg/L, where morning-afternoon fluctuations ranged from 4.02 to 8.92 mg/L.

The optimal pH value for vannamei shrimp culture is 7.5–8.5, with a fluctuation range of 0.5 (Reddy & Mounika 2018). The salinity value obtained was 34 ppt. The shrimp are able to naturally grow between 0 and 40 ppt, due to the fact that shrimp possess an osmose hemolymph metabolism system (Boyd 1998; Maica et al 2014; Chand et al 2015; Esparza-Leal et al 2018). Therefore, an optimum level is around 20–25 ppt (Boyd 1998). The average temperature value obtained in the study was 27.5^{0}C, which is optimum for shrimp growth. This was in accordance with the results of Wyban et al (1995), where the optimal value was at 27–30^{0}C. This is an important influence on the fluctuations in pond productivity (Prapaiwong & Boyd 2012). It is possible to state that the concentration levels of DO, pH, salinity and temperature during the shrimp cultivation period were within the optimum range.

The alkalinity of the pond was recorded and the values were situated between 124 mg/L and 192 mg/L, with a mean value of 154 mg/L. The amount of CO_3^{2-} and HCO_3^- ions averaged at 29 mg/L and 124 mg/L, respectively. During the cultivation period, the average concentration of phosphate was 0.67 mg/L, with the highest level being 1.98 mg/L. The mean value of nitrite was 0.29 mg/L, with a peak of 0.78 mg/L. The mean value of TAN was 0.08 mg/L, with the highest level of 0.26 mg/L. The level of TOM averaged at 101.41 mg/L, within the range from 59.35 mg/L and 130.57 mg/L.

The average abundance of plankton as a biological parameter was 5.05x10^5 cell/mL, within the range of 1.28x10^5 and 17.8x10^5 cell/mL. The mean total density TVC obtained was 6.42x10^2 CFU/mL, within a range of 0.00x10^2 and 16.8x10^2 CFU/mL. Conversely, the average TBC was 1.96x10^5 CFU/mL, within the range of 0.03x10^5 and 8.00x10^5 CFU/mL. Furthermore, the values of plankton abundance were different in each pond, due to the differences in the input of nutrients and, therefore, plankton structure and abundance were influenced by the tropic status of the waters, because of the accumulating nutrient (Case et al 2008). In addition, a higher input of feed affects the rate of decomposition by microorganisms. Therefore, the abundance of bacteria in this result was good for shrimp culture, up to 10^4–10^6 CFU/mL, which is in accordance with the results of Fernandes et al (2010). Generally, the average TBC is 10^3–10^4 CFU/mL (Tookwinas 2000), but that of TVC or bacteria as a whole is influenced by water quality parameters, including pH, salinity, temperature and mineral ions (Goarant et al 2000; Alfiansah et al 2018).

The high level of TOM was due to the length of the shrimp culture period. Thus, there is an accumulation of waste from leftover feed, feces, plankton lysis and other detritus in the pond sediments (Lemonnier et al 2010). The alkalinity value was extremely high, the recommended value being between 50–150 mg/L (Wurts 2002). The TAN level showed an appropriate range, where the recommendation for intensive shrimp culture is <0.1 mg/L (Edhy et al 2010). The amounts of nitrites and phosphates tend to exceed the recommendation, which is <0.2 mg/L (Bhatnagar & Devi 2013). The high level of phosphate was due to the construction of ponds, which applied geomembrane plastic in an attempt to affect phosphate released in the soil.

Based on the results of the correlation test, the concentration of DO in aquaculture ponds is related with water quality parameters, and its correlation with physico-chemical data is presented in Table 3. Its association with aquatic biological parameters can be observed in Table 4. Data indicates a negative relationship with the physics-chemical parameters covering temperature, phosphate, nitrite, TAN and TOM, while no relationship occurred with pH, salinity, CO_3^{2-}, HCO_3^- and alkalinity. This is in accordance with the opinion of Bui et al (2013), who state that the level of oxygen solubility will continue to decrease, along with the increase of temperature intensity and decomposition of inorganic compounds. Moreover, based on biological parameters, a negative correlation occurred with the TVC and TBC. The increasing level of bacteria abundance will make the availability of oxygen in the ponds become diminished due to its use in decomposition processes (Aldunate et al 2018).

Table 2

The average value of water quality parameters during the shrimp culture period

Quality parameter		*Ponds*							
		C1	C2	C3	C4	C5	C6	C7	C8
DO (ppm) [1]	Mean	4.83±2.1	4.69±2.1	4.59±2.0	4.66±2.0	4.79±2.1	4.73±2.1	4.84±2.1	4.56±1.1
	Range	4.03-8.92	4.02-7.74	4.14-8.17	4.32-7.57	4.04-8.80	4.01-7.40	4.02-8.42	3.72-8.32
pH (ppm) [1]	Mean	7.9±0.2	7.8±0.2	7.8±0.3	7.8±0.2	7.9±0.2	7.9±0.3	7.9±0.2	7.9±0.2
	Range	7.7-8.0	7.7-8.0	7.6-8.0	7.7-8.0	7.7-8.0	7.7-8.1	7.7-8.1	7.7-8.1
Sal (ppt) [1]	Mean	35±1.3	32±2.9	34±1.8	35±1.5	34±2.0	33±2.4	35±1.7	34±1.8
	Range	35-35	32-32	34-34	35-35	34-34	33-33	35-35	34-34
T (^{0}C) [1]	Mean	27.5±9.1	27.4±9.1	27.4±9.1	27.5±9.1	27.5±10.0	27.4±9.1	27.5±9.9	27.5±9.1
	Range	26.7-28.2	26.7-28.4	26.8-28.1	26.8-28.1	26.8-28.2	26.7-28.1	26.7-28.2	26.7-28.2
CO_3^{2-} (ppm) [2]	Mean	21±7.2	28±4.1	24±6.2	32±8.8	30±9.3	29±7.2	30±9.3	39±9.3
	Range	16-32	24-32	16-32	16-48	24-56	24-48	16-48	24-32
HCO_3 (ppm) [2]	Mean	124±14.2	124±16.7	134±16.6	121±13.6	124±9.3	128±22.4	128±17.4	113±31.1
	Range	100-144	104-148	108-168	100-140	100-136	80-156	100-152	104-158
Alk (ppm) [2]	Mean	146±13.1	152±18.1	158±14.6	153±12.4	154±13.6	157±17.4	159±11.4	153±13.7
	Range	124-164	132-180	140-192	132-172	132-184	128-180	144-180	136-180
PO_4^-(ppm) [2]	Mean	0.60±0.5	0.68±0.4	0.58±0.4	0.64±0.5	0.66±0.4	0.64±0.4	0.63±0.5	0.94±0.7
	Range	0.05-1.37	0.02-1.04	0.02-1.31	0.00-1.73	0.07-1.28	0.01-1.22	0.01-1.57	0.04-1.98
NO_2^- (ppm) [2]	Mean	0.33±0.3	0.31±0.2	0.33±0.3	0.28±0.2	0.29±0.3	0.28±0.2	0.28±0.2	0.26±0.2
	Range	0.01-0.71	0.01-0.78	0.00-0.67	0.04-0.62	0.01-0.66	0.02-0.59	0.03-0.59	0.01-0.58
TAN (ppm) [2]	Mean	0.06±0.05	0.07±0.05	0.09±0.1	0.08±0.05	0.08±0.1	0.07±0.05	0.09±0.1	0.09±0.1
	Range	0.01-0.15	0.00-0.15	0.00-0.26	0.02-0.16	0.00-0.24	0.00-0.17	0.00-0.23	0.00-0.25
TOM (ppm) [2]	Mean	97.58±16.0	99.27±13.1	101.47±16.7	101.72±16.5	102.17±18.3	104.07±14.7	103.21±18.9	101.83±16.1
	Range	63.89-116.29	73.59-123.62	62.91-122.2	68.85-125.01	73.63-130.57	83.34-127.79	59.35-126.4	67.66-127.79
Plt (cell/ml) [2]	Mean	5.07±2.4	4.99±4.5	3.93±1.4	6.01±4.4	4.63±2.5	6.21±1.1	4.73±3.0	4.83±1.7
	Range	1.32-8.95	1.30-15.9	2.15-6.93	1.28-17.8	1.50-10.1	3.95-11.3	1.53-12.8	1.60-6.85
TVC (CFU) [2]	Mean	5.91±471.2	5.83±515.2	8.18±486.5	6.10±523.4	5.54±508.2	5.73±514.8	7.78±744.6	6.33±470.7
	Range	0.00-1.48	0.30-16.8	1.40-14.6	0.20-16.7	0.30-1.77	0.03-1.74	0.04-2.65	0.20-14.0
TBC (CFU) [2]	Mean	1.54±1.6	2.08±2.2	2.76±2.5	1.51±1.2	1.86±1.8	1.59±1.6	2.39±2.6	1.93±2.1
	Range	0.14-5.70	0.40-7.33	0.07-7.00	0.25-3.95	0.03-5.79	0.13-5.53	0.08-8.00	0.23-6.00

Note: [1] - daily monitored; DO - dissolved oxygen; Sal - salinity; T - temperature; [2] - weekly monitored; Alk - alkalinity; TAN - total ammonia nitrogen; TOM - total organic matter; Plt – plankton abundance; TVC - total Vibrio count; TBC - total bacteria count.

DO is a parameter indicating the productivity rate of aquaculture ponds (Delgadillo-Mirquez et al 2016; Joseph et al 2017). Hence, its concentration is highly related to the solubility of chemical compounds. An elevated level leads to faster nitrogen fixation, as well as phosphate decay (Slade et al 2011). Conversely, a decline in oxygen solubility leads to an elevation in ammonia toxicity (Sriyasak et al 2015), and this parameter is highly influenced by the temperature in intensive ponds (Boyd 1998; Islam et al 2004b; Ruiz-Velazco et al 2010). A high stocking density contributes to the level of oxygen consumption in the decomposition process of organic materials by bacteria (Chang & Ouyang 1988). Therefore, shrimp growth is indirectly highly influenced by physical, chemical and biological factors in the ponds (Cardona et al 2016). This is in line with the report by Joseph et al (2017), which stated that a lower concentration of bacteria in the pond is positively correlated with the decline in ammonia, nitrate, nitrite, DO and pH levels.

Table 3

The relationship between DO and physics-chemical parameters of water

Parameter		*pH*	*Sal*	*T*	*CO_3^{2-}*	*HCO_3*	*Alk*	*PO_4^-*	*NO_2^-*	*TAN*	*TOM*
DO	Pearson correlation	-0.026	-0.102	-0.743″	0.173	-0.099	0.018	-0.652″	-0.742″	-0.361″	-0.788″
	Sig(2-tailed)	0.812	0.342	0.000	0.106	0.360	0.865	0.000	0.000	0.001	0.000
	N	88	88	88	88	88	88	88	88	88	88

Note: ‵ - correlation is significant at the 0.05 level; ″ - correlation is significant at the 0.01 level; DO - dissolved oxygen; Sal - salinity; T - temperature; Alk - alkalinity; TAN - total ammonia nitrogen; TOM - total organic matter.

Based on correlation test and descriptive analysis, the concentration of nitrite, TOM, and TVC have fluctuations in values that are above the water quality standard for intensive shrimp culture. The dynamics of water quality parameters have a close relationship and an indirect influence on the shrimp growth rate and the productivity capacity of aquaculture (Chen et al 2019). The effect of DO, nitrite, TOM and TVC parameters on shrimp growth rate can be partially seen in Figure 3. The effect of fluctuations in DO levels on shrimp growth rates in ponds, can be characterized by a regression formula, with the following equation:

$y=5.118+0.015$ ($R^2=0.044$)

It means that fluctuations in DO levels in ponds affect shrimp growth in about 4.4%, while the other 95.6% is influenced by other factors. In the shrimp metabolic system, DO has more important implications for the physiological response of shrimp than in the growth system (Yan et al 2014; Qiang et al 2019). In white shrimp, the growth rate is influenced 75% by the effectiveness of nutrients from feed (Nunes et al 2006).

Table 4

The relationship between dissolved oxygen and other physico-chemical parameters of water

		DO	*∑Plankton*	*TVC*	*TBC*
DO	Pearson correlation	1	0.108	-0.270′	-0.425″
	Sig(2-tailed)		0.317	0.011	0.000
	N	88	88	88	88

Note: ‵ - correlation is significant at 0.05 confidence level; ″ - correlation is significant at 0.01 confidence level; DO - dissolved oxygen; ∑Plankton - plankton abundance; TVC - total vibrio count; TBC - total bacteria count.

The effect of nitrite (NO_2) on the growth rate of shrimp during the culture period can be characterized by the following equation:

$$y=1.9+10.303\ (R^2=0.752).$$

Nitrite affects the growth rate of shrimp by 75.2%, while 24.8% is influenced by other factors. High levels of nitrite have an adverse effect on water quality parameters and shrimp growth (Hoang et al 2018). High nitrite concentration (NO_2) also affects feed intake, increases oxygen consumption, ammonia excretion system and moderately causes mortality (Valencia-Castaneda et al 2018). In general, increased nitrite levels in ponds are triggered by environmental fluctuations in aquaculture ecosystems (Soares et al 2020).

The growth rate of shrimp is also partially influenced by the increase of the levels of organic matter and the abundance of Vibrio bacteria in ponds. The effect of increasing organic matter levels in ponds on shrimp growth rates can be seen in the following regression formula:

$$y=24.309+0.292\ (R^2=0.119)$$

The organic matter content in ponds will affect the shrimp growth rate by 11.9%. For the influence of abundance of Vibrio bacteria on shrimp growth rates, the following regression equation was obtained:

$$y=7.654+0.001\ (R^2=0.020)$$

The abundance of Vibrio bacteria in ponds partially influences the shrimp growth rate by 2%. The increase in the density of Vibrio bacteria in ponds was triggered by poor environmental parameters due to excessive concentrations of organic matter (Eiler et al 2006; Takemura et al 2014). The influence of Vibrio abundance on growth rate is minor, due to the fact that Vibrio is mainly saprophytic and pathogenic, so it has a more important impact on the immune system of shrimp (Sotomayor et al 2019; Kewcharoen & Srisapoome 2019).

In this study, the nitrite is the parameter that has the greatest influence on the shrimp growth rate. The increase of nitrite is triggered by an increase of the feeding frequency and the amount of dissolved organic matter in the pond due to the growth of the shrimp biomass (Bardera et al 2019). Shrimp are sensitive to high nitrite levels accompanied by acidic pH conditions because they will cause physiological stress and will reduce the retention of nutrient intake (Soares et al 2020). Acute nitrite toxicity in the water will reduce the content of shrimp oxyhemocyanin, which affects the immune system and metabolism, as well as the balance of acid base levels in the shrimp body, so that the shrimp will die slowly (Chen & Cheng 1995; Guo et al 2013; Ramirez-Rochin et al 2017).

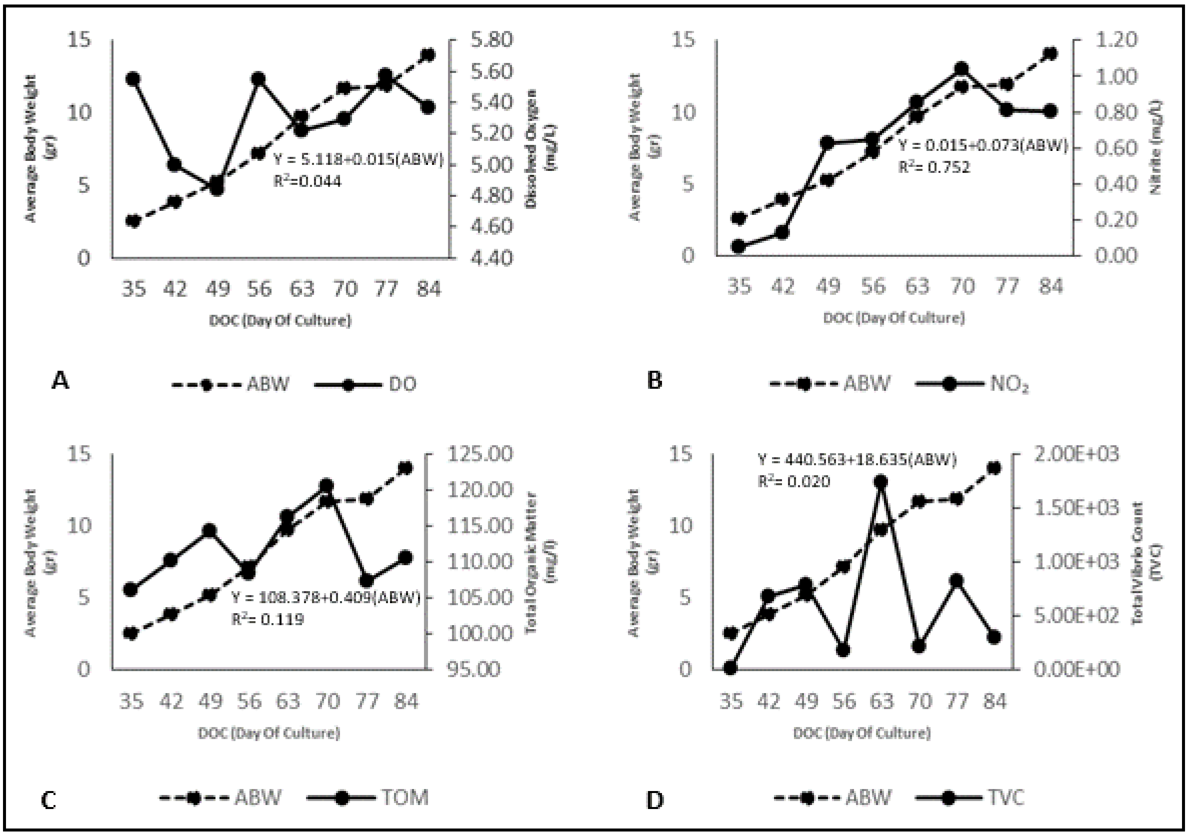

Figure 3. Effect of water quality on shrimp growth rate; ABW – average body weight. A - dissolved oxygen; B – nitrites; C - total organic matter; D - total Vibrio count.

Conclusions. Based on the results, the dynamics of dissolved oxygen concentration during the shrimp culture period are characterized by a normal level of fluctuation, with the highest concentration being 7.35 mg/L, at the age of 9 days, and the lowest concentration being 4.25 mg/L, on day 41, in the post period of the blind feeding. Furthermore, the solubility of dissolved oxygen in the ponds generally had a positive correlation with the temperature and negative correlations with phosphate, nitrite, TAN, TOM, TVC and total bacterial content.

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