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WATER QUALITY FLUCTUATIONS IN SHRIMP PONDS DURING DRY AND RAINY SEASONS

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ABSTRACT

Season and water quality are essential indicators in the life cycle of pond ecosystems. The season is a natural factor affecting the level of water quality dynamics in shrimp cultivation in ponds. This study aims to evaluate the dynamics of differences in water quality parameters in intensive *Litopenaeus vannamei* ponds during dry and rainy seasons. This current study applied an *ex post facto* causal design based on actual field conditions. During the rainy season, water quality parameters tended to fluctuate dynamically, with the parameters of phosphate (PO_4), nitrite (NO_2), and total organic matter (TOM) exceeding the threshold value of water quality standards for aquaculture, with a PO_4 value of 0.734 mg/L, a NO_2 of 0.180 mg/L, and a TOM of 101.29 mg/L. In the dry season, water quality parameters remained stable, with only the phosphate parameter showing a value above the water quality standard threshold of 0.633 mg/L. Based on the trend of fluctuations in the two seasons, a model of equation Y = 3.979 + 0.814x was made with a significance value <α (0.05), which means that the two seasons positively correlated with the impact on fluctuations of water quality in the ponds. The results of the dynamic modelling analysis showed contradictions in water quality and nutrients during rainy and dry seasons. Water quality parameters in intensive *L. vannamei* cultivation during dry and rainy seasons fluctuated dynamically and differed according to the type of weather conditions and the current season.

Keywords:
L. vannamei
Modelling
Season
Nutrients
Weather

How to Cite

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INTRODUCTION

Whiteleg shrimp *L. vannamei* is mainly farmed in the coastal areas of Indonesia. Compared to other species, whiteleg shrimp offers a few advantages, including a better feed conversion ratio, higher survival rate, and greater disease resistance (Mangampa and Suwoyo, 2010). The productivity level of intensive whiteleg shrimp cultivation ranges from 49-63 tons/ha (Lailiyah et al., 2018). Several elements, including the environment, climate, production resources, and cultivation techniques impact the productivity of whiteleg shrimp cultivation (Nguyen et al., 2020). Whiteleg shrimp is exceptionally tolerant of environmental fluctuations and water quality requirements. Shrimp farming is the main activity of the coastal community (Ariadi et al., 2019).

Water quality is the most important variable for determining the sustainability of shrimp cultivation (de los Santos et al., 2020). Water quality in *L. vannamei* cultivation is affected by various factors such as environment, climate, and treatment (Venkateswarlu et al., 2019). Shrimp in ponds are suitable and less sensitive to stress if water quality remains stable. Stable water quality parameters improve productivity and reduce the frequency of disease outbreaks (Ariadi et al., 2020). Healthy cultivated shrimp benefit from aquatic ecosystem stability in pond ecosystems (Qiao et al., 2020).

Aquaculture systems have dynamic water quality parameters (Estim et al., 2019). The value of water quality parameters fluctuates continuously. Temporary fluctuations in water quality are influenced by changes in weather conditions and seasonal factors (Eccles et al., 2020). This circumstance could result in daily fluctuations of water quality parameters in ponds during the cultivation period, as the weather fluctuates and is mitigated under the ongoing seasonal trend (Yue et al., 2020). Hence, this study aimed to investigate the dynamics of differences in water quality parameters in intensive *L. vannamei* cultivation ponds during dry and rainy seasons.

MATERIALS AND METHODS

This research was conducted in *L. vannamei* intensive ponds in Cibungur Village, Pandeglang Regency, Banten Province. The research was conducted during one cycle of shrimp cultivation between January and March 2018 for the rainy season cultivation, and between July and September 2018 for the dry season cultivation. The research method applied an *ex post facto* causal design based on actual conditions in the field during one cycle of *L. vannamei* cultivation period. Five ponds of 3200 m^2 were investigated, each with a stocking density of 120 shrimp/m^2. The operational aquaculture management implemented in the ponds refers to the CBIB (Good Fish Farming Methods) procedure, with research variables observed, including indicators of water quality parameters in the pond.

Water quality parameters measured as research variables were dissolved oxygen, pH, temperature, and salinity, which were measured in situ every day at 06.00 a.m. and noon, as well as the parameters TOM, CO_3^{2-}, HCO_3-, alkalinity, TAN, nitrite, and phosphate, which were observed every seven days. Dissolved oxygen was measured using a YSI 550i dissolved oxygen meter. The pH was measured using a Eutech EC-pHTestr. In addition, the pond water temperature was measured in situ using a mercury thermometer, while the salinity was measured using an Atago MASTER-S10 refractometer. Weekly samples of water quality parameters from the top, middle, and bottom of the ponds were collected using a water sampler. Furthermore, these samples were stored in a 250-mL sample bottle container and tested at the Water Quality Laboratory for Examination of Fish and Environmental Diseases in Serang Regency, Banten.

The collected water quality data were classified based on the measurement period. To determine the level of differences in fluctuations in water quality parameters during dry and rainy seasons of shrimp cultivation, quantitative descriptive analysis of data using Microsoft Excel was applied. Using Stella version 9.0.2, a modeling analysis was performed to identify the level of relationship between variable parameters, and a correlation test was performed to determine the correlation of water quality parameters in both seasons.

RESULT AND DISCUSSION

Water quality parameters during the rainy season

Table 1 depicts the values of water quality parameters during the rainy season cultivation period. The results showed that it still conformed to water quality standards for intensive *L. vannamei* cultivation, namely pH of 7.5-8.5, salinity of 15-33 ppt, dissolved oxygen (DO) of >4 mg/L, brightness of 25-30 cm, temperature 24-31 ºC, alkalinity of >120 mg/L, and Total Ammonia Nitrogen (TAN) of <0.1 mg/L (Ariadi et al., 2021). On the other hand, the concentrations of phosphate, nitrite, and total organic matter (TOM) parameters were found to exceed water quality requirements for intensive *L. vannamei* cultivation. The standards for phosphate and nitrite parameters are recommended at <0.1 mg/L, while the total organic matter parameter is at <90 mg/L (BSN, 2014). Water quality parameters are critical indicators to determine the status of the ecological feasibility of the aquaculture operational cycle (Ariadi et al., 2019). Stable fluctuations in water quality parameters positively correlate with productivity during the shrimp culture cycle (Casillas-Hernandez et al., 2007).

Season and water quality factors considerably affect the production cycle of shrimp farming (Aziz et al., 2018). Salinity and temperature parameters regularly drop destructively during the rainy season (Chowdhury et al., 2019). The decrease in the salinity is caused by high rainfall and the lower salinity of rainwater.

Table 1. Value of water quality parameters during the rainy season

Parameter	Pond					Standard*
	C1	C2	C3	C4	C5	
pH	7.4 – 8.3 7.9 ± 0.22	7.4 – 8.3 7.8 ± 0.21	7.3 – 8.4 7.8 ± 0.25	7.4 – 8.4 7.8 ± 0.22	7.3 – 8.3 7.9 ± 0.19	7.5-8.5
Salinity (gr/L)	19 – 36 27 ± 6.92	19 – 36 27 ± 6.74	20 – 36 27 ± 6.72	19 – 36 27 ± 6.76	19 – 37 28 ± 7.06	15-35
DO (mg/L)	4.64 – 7.03 5.65 ± 0.52	4.64 – 6.85 5.52 ± 0.48	4.64 – 6.76 5.46 ± 0.48	4.65 – 6.53 5.47 ± 0.40	4.63 – 7.22 5.56 ± 0.52	>4
Brightness (cm)	20 – 110 38 ± 20.31	25 – 90 58 ± 45.96	20 – 120 40 ± 20.05	25 – 100 35 ± 13.77	20 – 100 37 ± 14.83	25-30
Temperature (^oC)	25.80 – 28.65 27.47 ± 0.59	25.85 – 28.55 27.42 ± 0.61	26 – 28.75 27.49 ± 0.60	26.25 – 28.85 27.52 ± 0.60	25.85 – 29 27.83 ± 0.61	25-32
CO_3 (mg/L)	16 – 32 20 ± 6.26	24 – 32 28 ± 3.91	16 – 32 24 ± 5.91	16 – 48 32 ± 8.36	24 – 56 31 ± 8.91	10-30
HCO_3 (mg/L)	100 – 144 123 ± 13.30	104 – 148 124 ± 15.91	108 – 168 135 ± 15.84	100 – 140 121 ± 13	100 – 136 124 ± 8.86	>100
Alkalinity (mg/L)	124 – 160 144 ± 11.11	132 – 180 152 ± 17.26	140 – 192 159 ± 13.89	132 – 172 153 ± 11.83	132 – 184 155 ± 13.02	>120
Phosphate (mg/L)	0.050 – 1.366 0.592 ± 0.43	0.019 – 1.042 0.685 ± 0.35	0.024 – 1.314 0.582 ± 0.37	0.003 – 1.728 0.643 ± 0.48	0.074 – 1.278 0.661 ± 0.41	<0.1
Nitrite (mg/L)	0.014 – 0.709 0.311 ± 0.25	0.012 – 0.785 0.310 ± 0.24	0.001 – 0.673 0.331 ± 0.25	0.043 – 0.621 0.277 ± 0.18	0.006 – 0.656 0.287 ± 0.28	<0.1
TAN (mg/L)	0.015 – 0.152 0.067 ± 0.06	0.000 – 0.152 0.067 ± 0.05	0.000 – 0.260 0.087 ± 0.08	0.021 – 0.160 0.079 ± 0.04	0.001 – 0.243 0.079 ± 0.08	<0.1
TOM (mg/L)	63.89 – 116.29 98.46 ± 15.65	73.59 – 123.62 100.19 ± 13.07	62.91 – 122.23 101.38 ± 16.69	68.85 – 125.01 100.27 ± 15.75	73.63 – 130.57 102.40 ± 17.60	<90

* Ariadi et al. (2021)

In addition, the lack of sunlight during the rainy season is responsible for a drop in temperature (Sriyasak et al., 2013). In tropical areas, temperature fluctuations during the rainy season tend to be very low compared to the peak seasons (Ariadi et al., 2019).

Water quality parameters during the dry season

The results showed that during the dry season of shrimp cultivation, the parameters of pH, salinity, dissolved oxygen, brightness, temperature, alkalinity, nitrite, TAN, and TOM were still below the threshold for water quality standards of *L. vannamei* cultivation. However, the phosphate concentration exceeded the threshold value of water quality standards. The high phosphate concentration in the dry season was due to increasing water temperature and salinity values, which saturated phosphate solubility in the ponds. Water parameters, including salinity and temperature, significantly impact shrimp metabolism and the dynamics of water quality parameters in ponds (Ravuru and Mude, 2014).

The value of water quality parameters in each pond during the dry season tended to be stable. The stability of water quality affects the operational cycle of cultivation (Ariadi et al., 2020). The results showed that temperature and pH levels remained stable between ponds (Table 2). Stable water temperatures during the dry season could improve survival rates and feed conversion ratios of shrimp cultivation (Hoang et al., 2020). Additionally, the stability of water pH levels enhances shrimp metabolism and all other biochemical processes occurring in pond water (Chen et al., 2015).

Fluctuations of parameters

The fluctuations in salinity and water temperature observed during the cultivation cycle are represented in Figure 1. According to a comparison of the graphs for the two different seasons, water temperature and salinity fluctuated during the rainy season with an average value of 27.63 ^oC and 30 ppt, respectively. During the dry season, water temperature and salinity remained constant, with an average value of 29.91 ºC and 34 ppt, respectively. The primary causes of daily fluctuations in temperature and salinity parameters in ponds are erratic weather and unpredictable rainfall conditions throughout the rainy season (Wang et al., 2020). On the other hand, because of the stable sun exposure during the dry season, water temperature remains stagnant, and salinity generally increases. A significant increase in salinity occurs during the dry season due to intensive evaporation (Rajmohan et al., 2021).

Salinity and temperature are parameters that have an essential effect on the metabolic process of shrimp. The salinity level of water affects hypertonic conditions in the shrimp osmoregulatory system (Delgado-Gaytan et al., 2020). Shrimp experience higher rates of osmotic load, oxygen consumption, and stress as a result of changes in the salinity of the water (Widodo et al., 2011). The value of temperature stability in pond water is highly dependent on the amount of intensity of sunlight on the water surface (Adiyana et al., 2017). The temperature in shrimp cultivation, in particular, affects the appetite level and increases the growth rate of shrimp.

Figure 2 represents fluctuations in alkalinity and pH levels throughout the shrimp cultivation period during rainy and dry seasons. During the dry season, the alkalinity ranges from 93 to 167 mg/L, whereas during the rainy season, it ranges from 137 to 177 mg/L. It showed that the alkalinity tended to decrease during the dry season, while fluctuating throughout the rainy season. Due to the fertilization process and exposure to rainfall, increased water CO_3 levels during the rainy season result in alkalinity oscillations, which are equivalent to having acidic qualities (del Rosario Rodero et al., 2018). In shrimp cultivation, alkalinity serves as a buffer for the pH value of the acid-base balance in the water (Whangchai et al., 2014).

The pH fluctuates steadily during both seasons, with the trend reflecting changes in alkalinity levels. The average pH value during the dry season was 8.1, whereas the average during the rainy season was 7.8. The pH value strongly influences the level of solubility of alkalinity elements in the water, and a high alkalinity value serves as an effective buffer against pH fluctuations (Saxena et al., 2019). The distribution of microorganisms and chemical parameters in pond water shifts as a result of changes in

Table 2. Value of water quality parameters during the dry season

Parameter	Pond					Standard*
	C1	C2	C3	C4	C5	
pH	7.9 – 8.4 8.1 ± 0.11	7.8 – 8.5 8.1 ± 0.12	7.8 – 8.5 8.1 ± 0.12	7.8 – 8.4 8.1 ± 0.13	7.7 – 8.5 8.1 ± 0.16	7.5-8.5
Salinity (ppt)	30 – 36 34 ± 1.28	26 – 36 32 ± 3.03	29 – 36 34 ± 1.79	31 – 36 35 ± 1.33	29 – 36 34 ± 1.93	15-35
DO (mg/L)	4.04 – 6.15 5.05 ± 0.43	4.01 – 5.94 4.96 ± 0.41	3.92 – 6.05 4.92 ± 0.38	4.08 – 6.04 4.93 ± 0.37	4.13 – 6.31 5.18 ± 0.40	>4
Brightness (cm)	30 – 120 45 ± 17.63	30 – 105 53 ± 14	30 – 105 48 ± 13.36	30 – 110 53 ± 17.35	35 – 105 55 ± 19.63	25-30
Temperature (ºC)	25.50 – 31.70 29.19 ± 1.17	25.50 – 31.70 29.25 ± 1.19	25.50 – 31.60 29.17 ± 1.11	25.50 – 31.70 29.20 ± 1.15	25.50 – 31.80 29.21 ± 1.14	25-32
CO_3 (mg/L)	8 – 32 24 ± 9.24	0 – 48 21 ± 15.90	8 – 40 26 ± 11.04	8 – 56 29 ± 17.19	8 – 40 24 ± 12.22	10-30
HCO_3 (mg/L)	88 – 124 101 ± 15.74	88 – 136 109 ± 16.77	60 – 132 95 ± 21.75	72 – 120 95 ± 17.43	84 – 120 102 ± 11.74	>100
Alkalinity (mg/L)	100 – 152 125 ± 19.92	96 – 184 130 ± 30.80	76 – 164 121 ± 29.28	80 – 176 124 ± 33.79	92 – 160 126 ± 22.37	>120
Phosphate (mg/L)	0.053 – 1.253 0.719 ± 0.46	0.009 – 1.238 0.607 ± 0.52	0.021 – 1.462 0.640 ± 0.60	0.024 – 1.110 0.602 ± 0.48	0.015 – 1.325 0.683 ± 0.54	<0.1
Nitrite (mg/L)	0.057 – 0.314 0.125 ± 0.09	0.005 – 0.251 0.110 ± 0.08	0.037 – 0.280 0.117 ± 0.08	0.021 – 0.195 0.063 ± 0.06	0.034 – 0.186 0.077 ± 0.05	<0.1
TAN (mg/L)	0.045 – 0.141 0.105 ± 0.05	0.001 – 0.082 0.066 ± 0.03	0.007 – 0.133 0.092 ± 0.06	0.042 – 0.076 0.064 ± 0.02	0.012 – 0.169 0.084 ± 0.05	<0.1
TOM (mg/L)	77.10 – 103.65 90.64 ± 10.18	79.63 – 101.12 90.29 ± 8.35	74.58 – 99.86 90.80 ± 9.25	80.90 – 108.97 92.85 ± 11.13	70.78 – 107.44 90.10 ± 11.39	<90

* Ariadi et al. (2021)

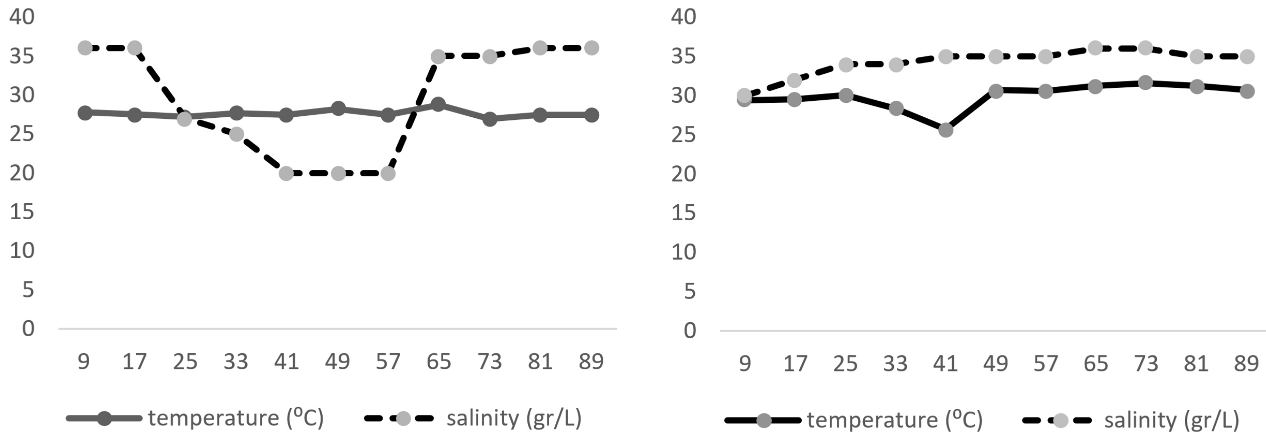

Fig 1. Temperature and salinity fluctuations during the rainy season (left) and dry season (right)

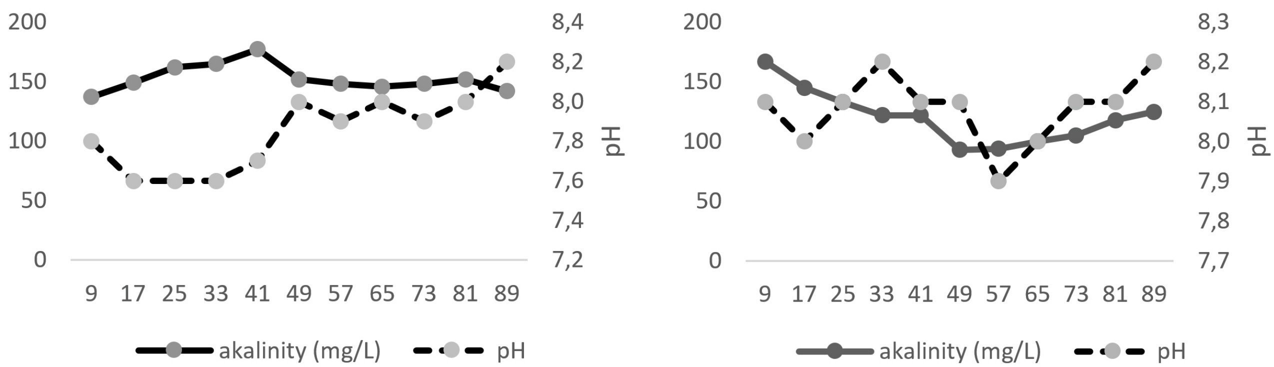

Fig 2. Alkalinity and pH fluctuations during the rainy season (left) and dry season (right)

the pH of the water (Supriatna et al., 2020). Extreme pH fluctuations result in an increase in physiological stresses and a decrease in the growth rate of cultured shrimp (Yu et al., 2020).

Parameters of water brightness and TOM concentrations fluctuated dynamically during the cultivation period of both rainy and dry seasons. During the rainy season, the brightness value tended to be lower or more concentrated, with an average of 35 cm compared to 36 cm during the dry season. This is because many suspended particles originate during the rainy season from plankton claps, lime particles, mud suspensions, and floc material that accumulate in the pond water column (Fleckenstein et al., 2020). During the rainy season, the plankton population in pond water tends to experience rapid mass blooming and death. High brightness values (transparent) lead to brighter shrimp colors, less solid, and less optimal growth rates (You et al., 2006). Brightness is an environmental, physical parameter that affects the level of abundance and diversity of plankton in aquaculture water (Rajaram et al., 2019).

The values of TOM showed an inline correlation with the brightness values during the cultivation period of both rainy and dry seasons (Fig. 3.). During the rainy season, the TOM values of 101 mg/L were slightly higher than in the dry season with a value of 100 mg/L. The higher value of TOM is affected by increasing feeding intensity and concentration of brightness values (Holanda et al., 2020). Brightness values and organic matter change dynamically with siphon activity, water turnover, calcification, and continuous feeding intensity in intensive shrimp pond water (Villanueva et al., 2019). The accumulation of organic waste, which increases with the days of shrimp culture, suspended particles, brightness readings, and brightness values are the key factors affecting the high concentration of organic matter in intensive ponds (Ariadi et al., 2019).

Dissolved oxygen is the most critical/crucial parameter for shrimp and other microorganisms in pond ecosystems (Ariadi et al., 2019). The fluctuations in dissolved oxygen concentrations in ponds were relatively stable during the rainy season but increased during the dry season. The dissolved oxygen concentration during the rainy season ranged from 5.24-6.52 mg/L, while during the dry season, it ranged from 4.85-5.60 mg/L (Figure 4).

The limited and unstable abundance of the plankton community and the lower intensity of sunlight exposure during the rainy season are the two factors that contribute to the tendency to decrease dissolved oxygen levels (Gokce et al., 2020). Oxygen production in ponds becomes more steady and possibly rises throughout the dry season due to increased exposure to sunlight intensity, photosynthetic activity, and water temperature (Correa-Gonzalez et al., 2014; Sekerc and Ozarslan, 2020). Dissolved oxygen is a crucial indicator that affects the dynamic patterns of aquatic ecosystems (Correa-Gonzalez et al., 2014). Low dissolved oxygen levels in ponds indicate that the ecosystem capacity for shrimp biomass is overloaded (Wafi et al., 2020).

Phosphate, nitrite, and TAN fluctuated dynamically and systematically during dry and rainy seasons (Fig. 4). Throughout the rainy season, the average concentrations of phosphate, nitrite, and TAN were 0.734 mg/L, 0.180 mg/L, and 0.076 mg/L, respectively. Furthermore, during the dry season, the average concentrations of phosphate, nitrite, and TAN were 0.633 mg/L, 0.303 mg/L, and 0.111 mg/L, respectively. These three variables varied throughout the cultivation period, with a tendency to increase with days of shrimp culture.

Due to the increased feed intake and raised shrimp biomass, the average concentration of the three parameters may be increased (Arifin et al., 2018). Nutrient abundance directly impacts the increased biogeochemical cycle intensity and the microorganism population in aquatic ecosystems (Kurten et al., 2019). The degree of primary productivity, as well as the diversity and overall quantity of plankton, are impacted by an abundance of nutritional components (Acri et al., 2004). The plankton ecosystem in ponds benefits from a proportionate increase in phosphate and TAN components (Zhao et al., 2020). However, the overly high nitrite and TAN solubility levels are toxic for the shrimp (Shan and Obbard, 2001). High nitrite and ammonia levels could also impact high oxygen consumption levels for decomposition processes in aquatic ecosystems (Wafi et al., 2021). The fluctuation rate of solubility by nitrite, TAN, and phosphate compounds affects the microorganism abundance and shrimp stress (Rajaran and Rameshkumar, 2019).

The following equation model was created by using a mathematical model to describe the relationship between the fluctuation levels of water quality parameters during dry and rainy seasons:

$$Y = 3{,}979 + 0{,}814x$$

According to the equation presented above, a one-point increase in the weather variable during dry or rainy seasons leads to a change of 0.814 in the value of the concentration of water quality parameters. The weather as a dynamic natural factor changes several environmental parameters in aquatic ecosystems, such as temperature, dissolved oxygen, and nutrient solubility (Komatsu et al., 2007). Conversely, as the seasons change, the concentration of water quality measures fluctuates over time (Yu et al., 2016). Seasonal implications on aquaculture activities have various consequences on other impacts, including decreased harvest production levels, plankton blooms, and anthropogenic environmental effects (Bakshi et al., 2020).

There was a significant correlation between water quality fluctuations during dry and rainy seasons ($P < 0.001$), as shown by the significance test value of 0.000 or a significance value lower than 0.05 for the significant value in the ANOVA table (Fig. 5). The level of output for different aquaculture is determined by factors related to the land, water, and season (Muhadjir et al., 1991). Variables affecting pond water quality fluctuate dynamically, depending on weather fluctuations (Yu et al., 2016). Seasonal changes have a considerable impact on the variability of water quality and the productivity of aquaculture in the tropics (Slembrouck et al., 2020).

The dynamic modeling analysis was based on the estimation of the causal loop model. The description of the causal loop model can be seen in Figure 5a. Using the causal loop model, an analysis of the existing parameters was carried out to determine the correlation effect of each variable. At the same time, the predictive interpretation of the correlation analysis of the relationship between water quality parameters and total nutrients in ponds is presented in Figure 5b.

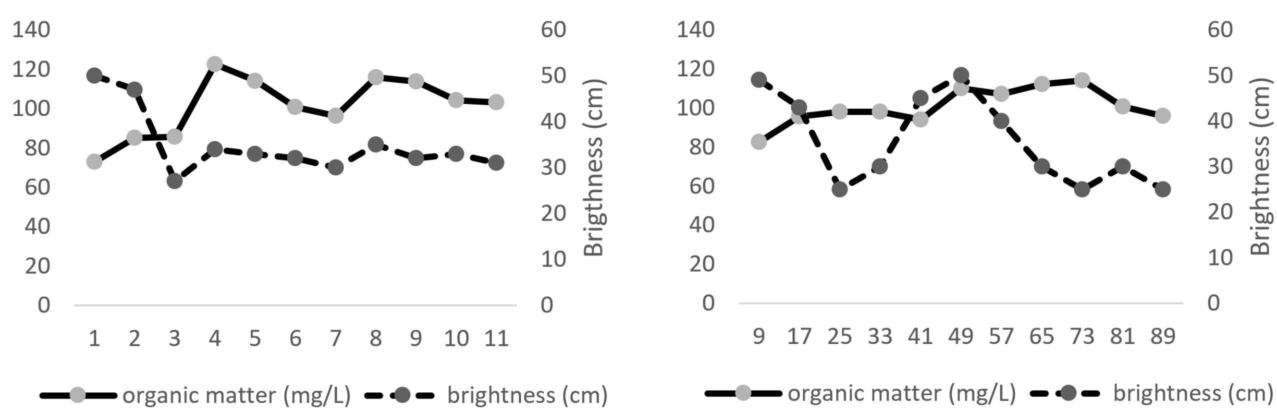

Fig 3. Brightness and TOM fluctuations during the rainy season (left) and dry season (right)

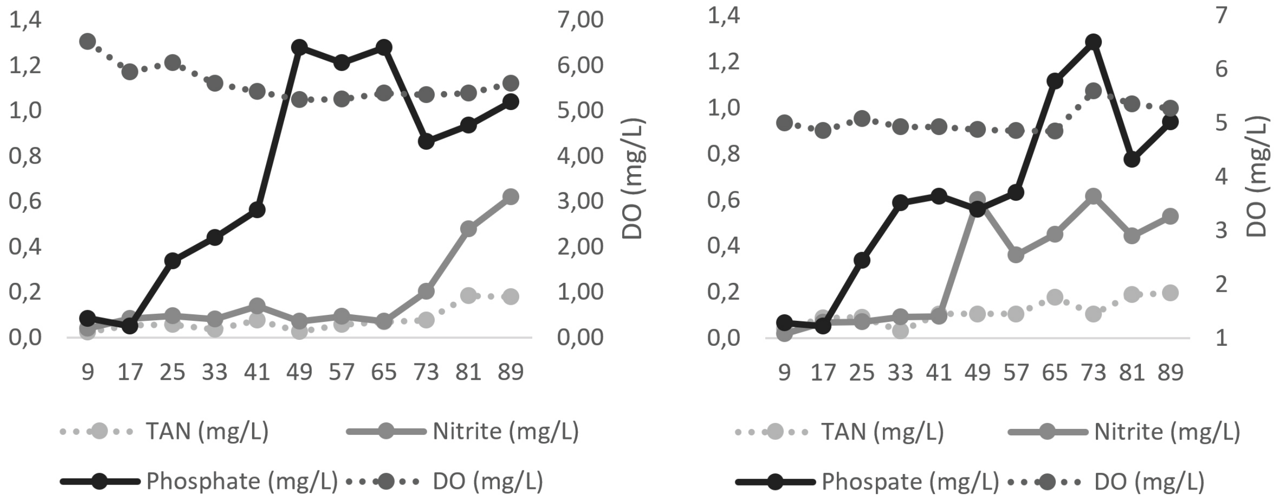

Fig 4. Fluctuations of phosphate, nitrite, total ammonium nitrogen (TAN), and dissolved oxygen (DO) during the rainy season (left) and dry season (right)

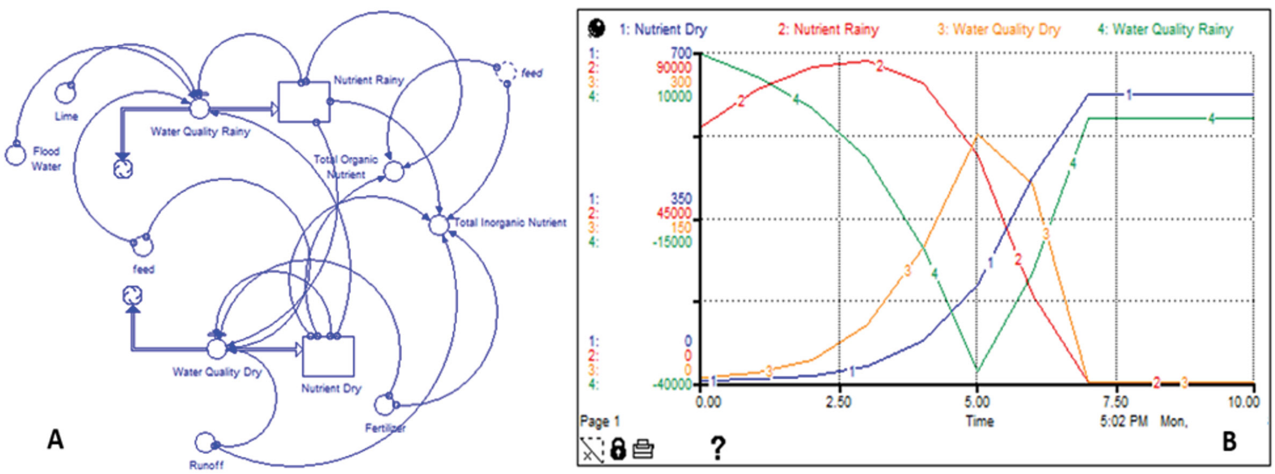

Fig 5. a) Causal loop dynamic model, b) Model simulation results between water quality parameters and nutrients

According to the results of dynamic modeling analysis, water quality parameters increased dynamically during the dry season, with an expected maximum value coefficient of 200. This implies that there could be a significant concentration increase in water quality parameters. Water quality parameters measure the aquatic environment, and functionality can change depending on the environment (Alam et al., 2021). The concentrations of water quality parameters were reported to decline dynamically throughout the rainy season, with a maximum decrease of -3,900. It also indicates that there could be a dramatic decrease in the quality of water concentrations during the rainy season. For biota and ecosystems, the rainy season is a challenge to adjust to abiotic changes (Chen et al., 2019).

In pond ecosystems, the dynamics of nutrient cycles are entirely influenced by water quality (Dien et al., 2019). Based on the dynamic modeling analysis, pond water quality conditions influence nutrient solubility. It is claimed that the aggregate total amount of nutrients in pond water rises during the dry season, with a maximum limit of 600 mg/L. The total amount of nutrients in the ponds typically decreases to a concentration point of 0 mg/L during the rainy season. This dynamic circumstance typically occurs during the final stage of shrimp cultivation. The most crucial moment for the pond ecosystem to preserve its environmental carrying capacity is during the last stage of shrimp cultivation (Ariadi and Mujtahidah, 2022).

There is a correlation between the total solubility of nutrients and fluctuations in water quality in pond water. Nutrients are key parameters that regulate the dynamic balance of the pond ecosystem (Yang et al., 2017). Fluctuations in water quality and nutrients affect the productivity level of pond water. The productivity level of pond water influences the level of dominance and abundance of plankton in the pond (Ariadi et al., 2022).

Overall, the trend of pond water quality parameters had a distinct fluctuation character during rainy and dry seasons. During the rainy season, pond water quality parameters tended to fluctuate dynamically, while during the dry season, they tended to fluctuate stably. The season is the primary indicator that carries out all the biological and chemical cycles in the aquatic ecosystem of shrimp ponds (Dien et al., 2019). In the dry season, pond water quality parameters tended to fluctuate stably because the environmental conditions of the water were much more stable due to the presence of sunlight exposure (Kamariah et al., 2019). During the rainy season, there was an oscillatory trend of rainfall and temperature variations, inducing pond water quality parameters to fluctuate dynamically (Villanueva et al., 2013). Temperature dynamics that occur seasonally have an impact on the solubility level of oxygen and other gaseous compounds in pond water (Ariadi et al., 2020; Ariadi et al., 2021).

The other characteristics observed from this study were the abundance of organic matter content in the rainy season and the high concentration of TAN and phosphate in the dry season. The intensity of high temperatures during the dry season makes the solubility of nutrients more active (Alam et al., 2021). That condition may occur because in the rainy season the level of waste particle suspension and organic particle abundance in the water tends to be higher due to the fluctuations in environmental conditions (Wu et al., 2019). Since the biota accelerated development and metabolism raises feed waste and excess oxygen consumption, the TAN and phosphate measurements are more likely to be higher during the dry season (Yin et al., 2021). Additionally, the values of pH and temperature were usually consistently higher during the dry season, which impacts the increasing levels of phosphate and TAN solubility. This confirms the result of a study by Widayat et al. (2010) that higher temperatures and pH levels enhance TAN solubility levels during the summer. Changes in water quality during rainy and dry seasons have a high level of relevance based on the overall research with the character and model of fluctuations induced by the same factors (season and environment). A high level of significance indicates a correlation among water quality parameters in rainy and dry seasons, which can fluctuate if there are fluctuations in the same variables (Ariadi et al., 2021).

Water quality parameters in intensive *L. vannamei* cultivation fluctuated dynamically during dry and rainy seasons. They fluctuated according to the types of weather and the time of year.

PROMJENE KVALITETE VODE U UZGOJU RAČIĆA TIJEKOM SUŠNE I KIŠNE SEZONE

SAŽETAK

Godišnje doba i kvaliteta vode bitni su pokazatelji u životnom ciklusu ekosustava ribnjaka. Sezona je prirodni čimbenik koji utječe na razinu dinamike kvalitete vode u aktivnostima uzgoja račića u ribnjacima. Ovo istraživanje ima za cilj procijeniti dinamiku razlika u parametrima kakvoće vode u intenzivnim ribnjacima *Litopenaeus vannamei* tijekom sušne i kišne sezone. Ova studija primijenila je *ex post facto* kauzalni dizajn temeljen na stvarnim uvjetima na terenu. Tijekom kišne sezone vrijednosti parametara kakvoće vode imale su tendenciju dinamičke fluktuacije, pri čemu su parametri fosfata (PO_4), nitrita (NO_2) i ukupne organske tvari (TOM) prelazili graničnu vrijednost standarda kvalitete vode za akvakulturu, s vrijednostima PO_4 od 0,734 mg/L, NO_2 od 0,180 mg/L i TOM od 101,29 mg/L. U sušnom razdoblju parametri kakvoće vode ostali su stabilni, a jedino je parametar fosfata imao vrijednost iznad praga standarda kvalitete vode od 0,633 mg/L. Na temelju trenda fluktuacija u dva godišnja doba napravljen je model jednadžbe $Y = 3{,}979 + 0{,}814x$ s vrijednošću značajnosti $<\alpha$ (0,05), što znači da dva godišnja doba pozitivno koreliraju s utjecajem na fluktuacije kvalitete vode u ribnjacima. Rezultati analize dinamičkog modeliranja pokazali su kontradikcije u kvaliteti vode i hranjivim tvarima tijekom kišne i sušne sezone. Parametri kakvoće vode u intenzivnom uzgoju *L. vannamei* tijekom sušne i kišne sezone dinamički su fluktuirali i razlikovali se ovisno o karakteru vremenskih uvjeta i aktualnoj sezoni.

Ključne riječi: *L. vannamei*, modeliranje, sezona, hranjive tvari, vrijeme

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