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The impact of water quality on the availability of phytoplankton and growth of *Litopenaeus vannamei*

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Abstract: This research analysed the availability of phytoplankton and the growth rate of Vannamei shrimp in relation to water quality changes. The research was carried out in February–March 2021 for a half cycle of shrimp cultivation in two ponds of the Brackish Water Fish Culture Probolinggo Laboratory in Probolinggo, East Java, Indonesia. The research used a descriptive method and included a survey. Sampling was made every two weeks for two months. Nine parameters were measured and ten shrimps were taken for a specific growth rate (*SGR*) measurement once per sampling. Data were analysed using the principal component analysis (PCA) and canonical correspondence analysis (CCA). Secondary data of water quality were added for the PCA. The results show that the phytoplankton found in the first pond consisted of Chlorophyta, Chrysophyta, and Cyanophyta, whereas the phytoplankton in the other pond included Chlorophyta, Chrysophyta, Cyanophyta, and Dinophyta. The abundance of phytoplankton ranged from $12–80\cdot10^3$ $cell\cdot cm^{-3}$, which indicated eutrophic waters. The PCA demonstrated that pH, nitrate, and total organic matter (TOM) significantly influenced phytoplankton abundance in the pond. In addition, water quality parameters, such as temperature, transparency, salinity, nitrite and phosphate levels, were tolerable in both ponds for the growth of shrimps. However, the level of pH was lower than the aquaculture quality standard, whereas those of nitrate, ammonia, and TOM were higher. The growth rate of Vannamei shrimp increased by $0.76–7.34\%\cdot day^{-1}$.

Keywords: algae, aquaculture, canonical correspondence analysis (CCA), dynamics of water quality, principal component analysis (PCA), Vannamei shrimp

INTRODUCTION

The Vannamei shrimp is an aquaculture commodity of high economic value [Nindarwi *et al.* 2020; Verdian *et al.* 2020]. It is easy to cultivate it in Indonesia, and therefore its cultivation can increase rapidly and continue to dominate the international seafood market [Amelia *et al.* 2021]. This shrimp is distributed naturally along the Pacific coast of Central and South America and has become the main species currently cultivated in countries around the Pacific Rim [Li *et al.* 2019]. The Vannamei shrimp is an euryhaline species able to adapt to a wide salinity range from 5 to 30‰ [Chen *et al.* 2015]. Another advantage of adopting the Vannamei shrimp culture is its relatively short cultivation period and high growth rate [Ghufron *et al.* 2020; Musa *et al.* 2020]. One super-intensive aquaculture of the Vannamei shrimp system has been applied in the Brackish Water Fish Culture Probolinggo Laboratory (Ind. Laboratorium Perikanan Air Payau dan Laut Probolinggo, PAPL).

The main problem often faced by cultivators, which result in the failure of the Vannamei shrimp culture, is poor water quality during the process. It is commonly faced by cultivators who apply intensive and even super-intensive systems [Arsad *et al.* 2017; Galang *et al.* 2019]. An intensive system culture requires special management in ponds, such as supplying more feed and paying attention to water quality for the production of a higher density shrimp [Thakur *et al.* 2018]. The main feed used for the intensive shrimp culture is artificial feed, so the organisms do not depend on natural feed in the pond [Musa *et al.* 2020]. Water quality in the Vannamei shrimp culture plays a very important role and affects the availability of phytoplankton and the growth of the Vannamei shrimp [Qiaoa *et al.* 2020]. The purpose of this study was to analyse the availability of phytoplankton and the growth rate of the Vannamei shrimp based on the dynamics of water quality in the PAPL ponds.

MATERIALS AND METHODS

RESEARCH SITE

This research was carried out in the shrimp ponds of the Brackish Water Fish Culture Probolinggo Laboratory (Fig. 1), located in Probolinggo, East Java, in February–March 2021. This period corresponds to a half cycle of shrimp rearing cultivation. There were two similar ponds used in this research; the only difference was the earlier start of shrimp cultivation in the first pond, which has its impact on the harvesting time. The pond area and depth were measured, and these were 1,600 m^2 and 1.1 m, respectively. The water used as cultivation media was natural seawater that had settled for a day and treated in the reservoir pond with chlorine. The resulting water from shrimp farming was deposited first in the waste disposal pond before being discharged into public waters through a mangrove area. There was no water exchange during the cultivation, except for the siphoning that was carried out six times during the aquaculture process. The total shrimp stocked in each pond amounted to 224,750 individuals with the stocking density of 140 ind.·m^{-2}. The shrimps were fed regularly five times a day using automatic feeder. The intensive shrimp ponds used continuous aeration to meet the oxygen demand for the Vannamei shrimp.

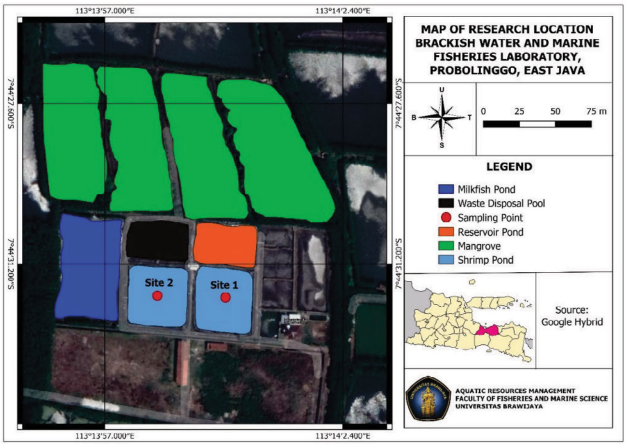

Fig. 1. Research location; source: own elaboration based on Google Hybrid, 2021

RESEARCH PROCEDURE

This study used the descriptive method and a survey. Sampling was conducted every two weeks for two months. Nine bottles of water samples were collected for measuring nine parameters, and ten shrimps were taken for a specific growth rate (*SGR*) measurement once per sampling. The sampling point was determined by a purposive sampling method [Purnamasari *et al.* 2021]. This method was used based on the consideration that the intensive shrimp ponds at the Brackish Water Fish Culture Probolinggo Laboratory had a water circulation system that was able to rotate water, and therefore, any sampling point is considered sufficient to represent the entire pond area. A water sample was taken in the water column and put on the sample container for water quality analyses. The sample was then analysed using the water quality parameters procedure [Hutami *et al.* 2020]. The procedure for identifying phytoplankton relied on observation through the Olympus CX31 binocular microscope with 100–400× magnification. Morphological identification was conducted using Prescott and Davis's identification books. The abundance of phytoplankton was calculated using the Neubauer haemocytometer [Rasit *et al.* 2016]. Subsequently, water quality measurements were carried out in-situ, including temperature (°C, thermometer), transparency (cm, Secchi disc), pH (pH meter: Lutron YK-2005WA), nitrite (mg·dm^{-3}, Hanna Instrument: HI 38049 Nitrite Test Kit), nitrate (mg·dm^{-3}, Hanna Instrument: HI 3874 Nitrate Test Kit), ammonia (mg·dm^{-3}, Hanna Instrument: HI 38049 Ammonia Test Kit), salinity (‰, salinometer), phosphate (mg·dm^{-3}, spectrophotometer: IKM/7.2.30/UPT-LKIL), TOM (mg·dm^{-3}, colorimeter), phytoplankton sampling (cells·cm^{-3}, plankton net of mesh size 25 μm), and *SGR* (%·day^{-1}, digital scales with accuracy within 0.01 g). Furthermore, shrimp samples were collected by using the Anco net. The value of the specific growth rate is calculated acc. to Suparlan *et al.* [2020] as follows:

$$SGR = \frac{\ln W_t - \ln W_0}{t} 100\% \tag{1}$$

where: SGR = specific growth rate (%·day^{-1}), W_t = shrimp biomass test at the end of study (kg), W_0 = shrimp biomass test at the start of study (kg), t = time (day).

Before weighing, shrimps were relieved of any trapped water, following which the weighing was carried out on a digital scale with an accuracy of 0.01 g. The specific growth rate (*SGR*) was used to calculate the growth percentage of shrimp weight per day and determine whether the water quality affected the weight growth of the Vannamei shrimp.

DATA ANALYSIS

Data were analysed using multiple linear regression, PCA, and CCA methods. Linear regression was used to model the linear relationship between the dependent variable (Y) and one or more independent variables (X). The multiple linear regression method was used if there was more than one independent variable. In the multiple linear regression, conditions must pass the multicollinearity test to avoid multicollinearity, which can be overcome by the PCA analysis. The results of the PCA analysis were then used to reduce multicollinearity between variables [Atteia *et al.* 2022] and remove multicollinearity among water quality parameters. The CCA is a multivariate analysis method that combines and analyse the information of species abundance with the information about variables from the same position [Datteo *et al.* 2017]. The CCA was used to analyse associations between independent variables and dependent variables and to understand the main drivers of the organism community structure [Tian *et al.* 2022]. Hilaluddin *et al.* [2020] showed that CCA the could be used to analyse associations between phytoplankton and environmental variable and to understand the main aspects of the phytoplankton community structure. The variable arrow length represents the strength of the phytoplankton species. Data analysis was performed using IBM SPSS Statistics 22 and PAST4 software.

According to Lavery *et al.* [2019], multicollinearity represents correlation between independent variables. Multicollinearity can be identified by the value of the *VIF* (variance inflation factor) and the value of tolerance in the coefficient table. A datum is said to have no multicollinearity if the VIF < 10 and the tolerance value is >0.10. A low tolerance value is the same as a high *VIF* value which indicates high collinearity. Multicollinearity that occurs in research data was overcome by the PCA. The method was used because the sample data in the study were much smaller than the number of variables used. The first step in data analysis using IBM SPSS Statistics 22 software is the multiple linear regression analysis performed to determine the occurrence of multicollinearity in research data.

The second step is PCA performance to overcome multicollinearity by reducing the data. In the third step, the data are analysed again using a multiple linear regression. In the fourth one, partial hypothesis testing (t-test) is carried out with a confidence level of 90% (α = 0.1). According to Shidik *et al.* [2015], the partial hypothesis test (t-test) is a statistical test used to determine whether an independent variable (independent) has a partial effect on the dependent variable. For the PCA in this study, we added secondary data in the form of measurement results of water quality parameters taken from Musa *et al.* [2021].

RESULTS AND DISCUSSION

DYNAMICS OF WATER QUALITY PARAMETERS

The water temperature measurement at site 1 and 2 (Tab. 1) in Vannamei shrimp ponds at the Brackish Water Fish Culture Probolinggo Laboratory provided results ranging from 28.5 to 30.3°C, water transparency from 22.5 to 38.75 cm, pH from 4.76 to 5.9, nitrite from <0.2 to >1 mg·dm^{-3}, nitrate approximately from <10 to >50 mg·dm^{-3}, ammonia from 1.6 to >3 mg·dm^{-3}, water salinity from 22 to 25‰, phosphate from 0.05 to 1.27 mg·dm^{-3}; and TOM from 60.04 to 236.37 mg·dm^{-3}. A good temperature for the Vannamei shrimp culture is 26–33°C [Abdelrahman *et al.* 2019], therefore the ponds were in optimal temperature range. The optimum transparency value supporting the growth of the Vannamei shrimp is 20–40 cm from the surface of the pond water [Kamilia *et al.* 2021]. The ponds again fell right inside the optimum range for water transparency. The optimum pH for Vannamei growth ranges from 7.5 to 8.0 with a tolerance of 7.0 to 8.5, a reasonable range for the life and growth of the Vannamei shrimp [Effendi, Elizal 2020]. Both Vannamei shrimp ponds were in low or sub-optimal condition since the pH level was too acidic because of the rainy season during the research. Rainwater can cause a decrease in the pH level, aided by the very high total value of organic matter which can also reduce the pH level. The optimal

Table 1. Water quality in the shrimp ponds

Parameter	Value		Standard quality	
	site 1	site 2	value	reference
Temperature (°C)	28.5–30.3	29.0–30.2	26–33	Abdelrahman *et al.* [2019]
Transparency (cm)	22.50–38.75	25.00–37.25	30–45	Katmoko *et al.* [2021]
pH	5.1–5.9	5.41–5.76	7.8–8.3	Millard *et al.* [2021]
Nitrite (mg·dm^{-3})	0.20–3.00	0.1–2.8	<0.5	Juliyanto *et al.* [2021]
Nitrate (mg·dm^{-3})	8.0–30.0	9.0–55.0	0.4–0.8	Kamilia *et al.* [2021]
Phosphate (mg·dm^{-3})	0.08–0.47	0.05–1.27	0.09–1.80	Nindarwi *et al.* [2021]
Salinity (‰)	23–25	22–23	0.5–45.0	Abdelrahman *et al.* [2019]
TOM (mg·dm^{-3})	60.04–236.37	71.42–216.46	<90	Musa *et al.* [2021]

Explanation: TOM = total organic matter.
Source: own elaboration based on the literature.

range of nitrite values in the Vannamei shrimp culture is <0.6 mg·dm^{-3} [MAS'UD, WAHYUDI 2018]. The nitrite parameter based on the results of the research in both Vannamei shrimp ponds was optimal and even exceeded the quality standard, but still tolerable for the organisms. The optimal range of nitrate in the Vannamei shrimp culture is 0.4–0.8 mg·dm^{-3} [KAMILIA *et al.* 2021]. The results of the nitrate parameters exceeded the quality standard so the condition was not optimal. The value of nitrite and nitrate in the ponds exceeded the quality standards due to the accumulation of feed residue and residual shrimp faeces during the cultivation process. The optimal range of salinity for the Vannamei shrimp is at 0.5–45‰ [ABDELRAHMAN *et al.* 2019]. In relation to the need for phytoplankton growth, the optimal value of phosphate is 0.09–1.80 mg·dm^{-3} [NINDARWI *et al.* 2021]. Based on the results of the study, salinity and phosphate levels came below optimal. The quality standard of the TOM value in the intensive system of the Vannamei shrimp culture is <90 mg·dm^{-3} [WAFI *et al.* 2020]. In the research, TOM parameters were not optimal.

SPECIFIC GROWTH RATE (*SGR*)

During first measurement, the specific growth rate of the Vannamei shrimp at site 1 was 5.15%·day^{-1} (week 2 and 4), and during the second measurement, the growth rate was 4.08% ·day^{-1} (week 4 and 6), whereas during the third measurement it was 2.44%·day^{-1} (week 6 and 8). During the first measurement, the specific growth rate of the Vannamei shrimp at site 2 was 5.70%·day^{-1} (week 2 and 4), during the second measurement, it was 7.34%·day^{-1} (week 4 and 6), whereas during the third measurement, it was 0.76%·day^{-1} (week 6 and 8). The best value of the specific growth rate for the Vannamei shrimp occurred during the second measurement at site 2, with the *SGR* value of 7.34%·day^{-1}. The results showed that the *SGR* value during the first and second measurements were higher than during the third measurement; this can be observed because the larger the age of the shrimp, the longer its growth. The Vannamei shrimp growth rate is also influenced by feed supply, aeration, and fertilisation in ponds [MUSA *et al.* 2021]. Shrimp production at the end of the rearing period was 35.73% (site 1) and 54.30% (site 2).

The ability to utilise good feed shows that the Vannamei shrimp can use nutrients in the feed well for its growth [PRAWIRA *et al.* 2014]. Shrimp growth is influenced by the density of shrimp kept at the time of cultivation [ARSAD *et al.* 2019]. Shrimp growth is lower when the stocking density in ponds is too high (100 ind. ·m^{-2}), since the competition for feed, space, and dissolved oxygen affects the growth of the Vannamei shrimp [BAEDLOWI *et al.* 2020]. The appetite loss in shrimps can interfere with shrimp growth, since it is also influenced by nutrients in the feed [EKAPUTRI *et al.* 2018].

PHYTOPLANKTON ABUNDANCE

The results of the phytoplankton identification obtained in the research ponds showed that there were three divisions at site 1 and four divisions at site 2. At site 1, the phytoplankton consisted of Chlorophyta, Chrysophyta, and Cyanophyta. At site 2, the phytoplankton consisted of Chlorophyta, Chrysophyta, Cyanophyta, and Dinophyta (Fig. 2). Chlorophyta can be found in such genera as *Chlorella*, *Cosmarium*, *Oocystis* and *Chlamydomonas*; Chrysophyta is comprised of *Cyclotella*, *Amphiprora* and

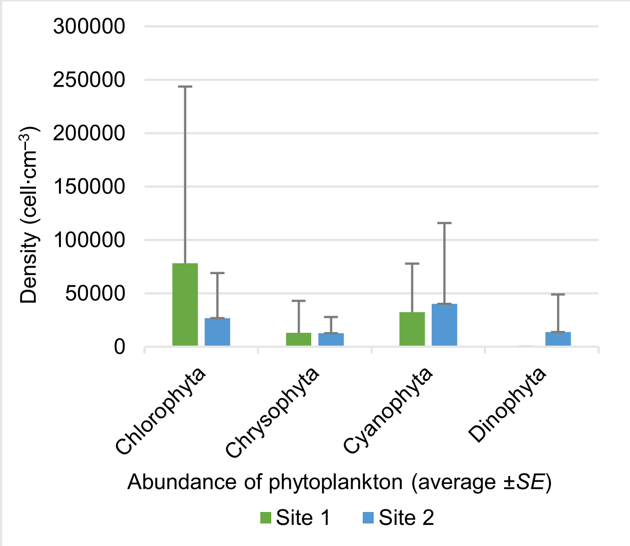

Fig. 2. Abundance of phytoplankton; *SE* = standard error; source: own study

Navicula genera; Cyanophyta consists of *Spirulina*. These genera are beneficial phytoplankton. However, harmful microalgae are also found, such as *Nitschia* and *Stephanodiscus* (Chrysophya); *Mycrocstis* and *Chroococcus* (Cyanophyta); and *Peridinium* (Dinophyta). The lowest average abundance of phytoplankton was the Dinophyta division at site 1 with a value of 0 cells·cm^{-3}, while at site 2 the lowest average was the Chrysophyta division with a value of 12,500 cells·cm^{-3}. The Chlorophyta division was often found at site 1 with the highest average value of 78,125 cells·cm^{-3}, while at site 2, Cyanophyta divisions were most often found with the highest average of 40,000 cells·cm^{-3}. The longest error bar line shows data that tend to fluctuate, while the short error bar line shows data that tend not to fluctuate. Based on the calculation of the abundance of phytoplankton, the average range is between 12,000 and 80,000 cells·cm^{-3}, which indicates that the water was eutrophic. According to KURNIANDA and HERIANTONI [2017], the total abundance of phytoplankton indicates that the pond water is eutrophic at the total abundance of more than 15000 cells·cm^{-3}. The abundance of phytoplankton is influenced by nutrients, i.e., nitrate and phosphate.

Chlorophyta play an important role in waters as single cell protein producers, but they can also interfere with water quality if their number is excessive and they cause the change in water colour and smell. Chlorophyta play an important role in the global carbon, nitrogen, and phosphorus cycles. This group of microalgae has tolerance to harsh weather conditions [ARSAD *et al.* 2021]. The dominance of the number and types of Chlorophyta can indicate the eutrophication of a water body [ARSAD *et al.* 2019]. Meanwhile, Chrysophyta are golden brown algae, most popularly in the form of flagellates [MCCAULEY *et al.* 2018]. Cyanophyta are usually found in eutrophic waters. This species causes a lot of pollution problems, such as disturbance to aquatic life habitats, increased toxic content, and change in taste and odour of drinking water, as well as an unpleasant appearance [ARSAD *et al.* 2019]. Cyanophyta are photosynthetic organisms that can easily be found in various aquatic environments [ARSAD *et al.* 2021]. Dinophyta are usually found in mesotrophic waters that show high availability of the organic matter because

Cyanophyta can execute photosynthesis by absorbing organic matter from water ponds [Zębek, Szymańska 2017]. Dinophyta can be seen at the lower levels of the pond where the nitrite content is not too high. They live in waters with abundant organic suspension which can support their growth [Campos *et al.* 2021].

There are differences in the abundance of phytoplankton in each sampling that can be seen in Figure 2. This is attributable to several factors, namely the weather at the time of sampling and light. Because phytoplankton conduct photosynthesis with the help of sunlight, their presence leads to the production of oxygen. According to a previous study, due to rainfall ponds get more rainwater and river water that carries nutrients and phosphates [Sidabutar, Srimariana 2020]. Apart from rainfall, factors that affect the abundance of phytoplankton is the amount of nutrients, such as nitrate and phosphate. The transparency is low and it leads to a decrease in the phytoplankton growth rate. In fact, the abundance of plankton in shrimp ponds can reflect water quality and growth rate of the Vannamei shrimp, so it can be used as an indicator of a successful shrimp culture [Musa *et al.* 2021]. The distribution and density of plankton respond to changes in physical, chemical, and biological conditions in the environment. The presence of phytoplankton can be used as an indication of pollution occurring in these waters [Sari *et al.* 2019a]. The growth and development of phytoplankton is related to the availability of nutrients, and phytoplankton grows and develops properly if their quantity is sufficient [Sari *et al.* 2019b].

RELATIONSHIP AMONG THE WATER QUALITY PARAMETERS IN VANNAMEI SHRIMP PONDS

According to Table 2, it can be seen that many water quality variables that were used as predictors in the multiple regression analysis are correlated to each other (multicollinearity) as indicated by their *VIF* values, which are greater than 10. Therefore, this may affect the result of the multiple linear regression analysis. Hence, we performed a PCA prior to the linear regression analysis to remove the multicollinearity. Our PCA results suggested the use of three principal components (PC) that reflect 10 water quality parameters (Tab. 3). The PC1 variable represents nitrite, ammonia, phosphate, and pH, whereas the PC2

Table 2. Multiple linear regression coefficients of phytoplankton abundance with water quality parameters acc. to model 1

Parameter	Unstandardised coefficient		*T*	Sig.	Collinearity statistics	
	B	standard error			tolerance	*VIF*
Constant	−1465379.84	4077586.856	−0.359	0.728		
Temperature	323730.534	261205.311	1.239	0.247	0.029	34.661
pH	−553135.526	320157.857	−1.728	0.118	0.011	89.955
Salinity	−8567.006	30922.313	−0.277	0.788	0.221	4.522
Transparency	−85037.607	51067.038	−1.665	0.130	0.032	31.440
Nitrate	−18000.075	29062.734	−0.619	0.551	0.066	15.083
Nitrite	−253671.213	236560.274	−1.072	0.311	0.223	4.478
Ammonia	−445517.001	150509.969	−2.960	0.016	0.148	6.758
Phosphate	−586957.089	313894.662	−1.870	0.094	0.272	3.683
TOM	1729.774	2702.225	0.640	0.538	0.097	10.338
SGR	−160409.219	49625.279	−3.232	0.010	0.193	5.187

Explanations: *B* = coefficient value, Sig. = significance value with probability 0.05, *VIF* = variance inflation factor, TOM = total organic matter, *SGR* = specific growth rate.
Source: own study.

Table 3. Multiple linear regression coefficients of phytoplankton abundance with reduction variables result (PC1, PC2 and PC3) acc. to model 1

Parameter	Unstandardised coefficient		*t*	Sig.	Collinearity statistics	
	B	standard error			tolerance	*VIF*
Constant	348000.000	74753.019	4.655	0.000		
PC1	15728.589	76694.979	0.205	0.840	1.000	1.000
PC2	174470.981	76694.979	2.275	0.037	1.000	1.000
PC3	−25642.132	76694.979	−0.334	0.742	1.000	1.000

Explanations: PC1 variable represents nitrite, ammonia, phosphate, and pH; the PC2 variable represents TOM, nitrate temperature; the PC3 variable represents salinity, and transparency and *SGR*; the other explanations as in Tab. 2.
Source: own study.

variable represents TOM, nitrate temperature. The PC3 variable represents salinity, and transparency and *SGR*. The values obtained from PC1, PC2, and PC3 were then processed through the regression analysis and proved to be free of multicollinearity (Tab. 4). Furthermore, based on the regression analysis and results of the partial hypothesis test (*t*-test) in Table 3, it can be concluded that partially, only the PC2 variable had a significant effect on the abundance of phytoplankton because it had a value of 0.037 which was below the sig value <0.05. Consequently, it can be said that temperature, nitrate, and TOM parameters, which were represented by PC2, are the significant water quality parameters that affect phytoplankton abundance.

Table 4. Rotated component matrix loading factor value (82.1% variance)

Parameter	Component		
	1	2	3
Temperature	−0.636	**0.689**	0.079
pH	**−0.957**	0.177	0.010
Salinity	0.115	−0.060	**0.921**
Transparency	0.338	−0.511	**0.595**
Nitrate	0.429	**0.803**	0.095
Nitrite	**0.917**	0.140	−0.056
Ammonia	**0.797**	0.264	−0.197
Phosphate	**0.744**	0.246	0.140
TOM	0.051	**0.907**	0.173
SGR	−0.223	0.067	**−0.890**

Explanations: TOM, *SGR* as in Tab. 2; determination of the variables into which component factors are determined by looking at the largest correlation value of each variable; the highest value for components are bolded.
Source: own study.

THE RELATIONSHIP BETWEEN PHYTOPLANKTON AND POND WATER QUALITY PARAMETERS

In this study, the canonical correspondence analysis (CCA) was used to determine the relationship between types of phytoplankton and environmental factors. Based on the results of the CCA triplot (Fig. 3), it was observed that the Dinophyta division tended to gain its maximum abundance at high concentrations of phosphate, nitrate, and nitrite. This is confirmed by Campos *et al.* [2021] findings. The proportion of Dinophyta was very low because the nitrite content was not too high, and Dinophyta tend to live in water bodies that have considerable accumulation of organic suspension so that its growth can be supported. Meanwhile, Cyanophyta was shown to prefer high concentration of nitrite and phosphate. Zębek and Szymańska [2017] stated that Cyanophyta are found in waters rich in nutrients. Cyanophyta can fixate N_2 from the air and is very easy to grow in high phosphate conditions. Moreover, Chlorophyta was found to be associated with transparency, nitrate, and salinity at high concentrations. Some Chlorophyta are usually found in enriched water [McCauley *et al.* 2018]. On the other hand, Chrysophyta was observed to be associated with moderate pH, phosphate, salinity, transparency, and nitrate concentrations, as well as low nitrite value [Nindarwi 2019]. Chrysophyta was usually found in water that did not have too many nutrients or that was a little more productive, and with optimum transparency [McCauley *et al.* 2018; Sidabutar, Srimariana 2020].

CONCLUSIONS

The results of water quality measurements in the Vannamei shrimp ponds revealed that conditions in the ponds were still tolerable and belonged to a standard quality for shrimp life. The positive quality measurements included temperature, transparency, salinity, nitrite, and phosphate. Meanwhile, the results of pH, nitrate, ammonia, and TOM in the Vannamei shrimp ponds were not optimal. This can also be seen from the growth of shrimp which improved with age. The results for the type of

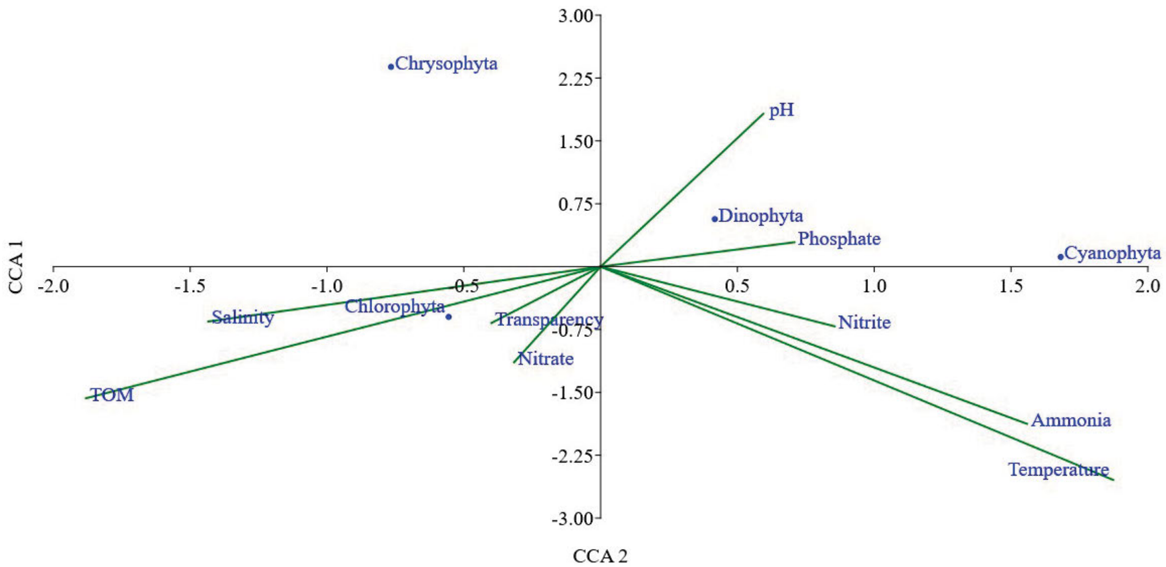

Fig. 3. Canonical correspondence analysis (CCA) triplot-diagram; source: own study

phytoplankton in the Vannamei shrimp pond (*Litopenaeus vannamei*) site 1 were obtained from Chlorophyta, which was the most commonly found species; site 2 consisted mainly of Cyanophyta, which was classified as native to mesotrophic to eutrophic waters. The partial multiple linear regression analysis reduced by the PCA led to the PC2 variable which had a significant influence on the abundance of phytoplankton because of the Sig. value <0.1, consisting of temperature, nitrate, and TOM parameters.

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