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Dynamics of Water Quality for Vannamei Shrimp Cultivation in Intensive Ponds in Coastal Areas

Rizky Kusma Pratiwi[1*], Mohammad Mahmudi[1], Abdul Rahem Faqih[1], Diana Arfiati[1]

[1] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Brawijaya University, Malang, Indonesia.

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Corresponding Author:
Rizky Kusma Pratiwi
rizkykusma@gmail.com

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Abstract: Cultivators increase production using intensive cultivation which applies stocking densities and feeding in high quantities, which triggers a decrease in water quality, both cultivation water and cultivation wastewater because it contains high levels of organic matter. Changes in water quality have an impact on plankton community structure. This research aims to determine the dynamics of the physical, chemical, and biological quality of cultivation media water and the disposal of vaname shrimp cultivation waste in Ujungpangkah District, Gresik Regency. The research was conducted in January 2023 using a survey method. Water and plankton samples were taken from reservoirs, ponds, and pond waste disposal sites. Sampling was carried out in vaname shrimp cultivation ponds in the Coastal Area of Ujungpangkah District, Gresik Regency. The physical and chemical quality of water has a pattern of changes up and down but is relatively the same and stable every week. All of these water quality parameters show a pattern of change that is quite good for the growth of vaname shrimp, but in waste disposal, the parameters for nitrate, phosphate, ammonia, and TOM are above the quality standards. The highest abundance of plankton is in waste dumps, with the highest phytoplankton coming from the Bacillariophyta phylum (49%), while zooplankton comes from the Rotifera phylum (54%). Regular monitoring of water quality in ponds and waste disposal sites is required so that it remains stable and safe for the environment.

Keywords: Cultivation; Waste; Pankton; Pond

Introduction

Vaname shrimp is one of the main commodities in the aquaculture industry because of its high economic value and high-demand product (Fajriani and Budiharjo, 2018). The increase in vaname shrimp production, according to the Director General of Aquaculture of the Republic of Indonesia, has experienced a significant increase of around ±14.86% every year (Cahyanurani and Dowansiba, 2022). High market demand causes cultivators to increase production by means of intensive cultivation which applies stocking densities and feeding in high quantities (Pamukti, 2019). Increasing production means that feeding will increase and allow several impacts to arise such as decreasing water quality, disease attacks, and the total death of vaname shrimp cultivation (Supono, 2017). Poor water quality is caused by inputs into the cultivation media, such as feed and feces of cultivated biota. According to the statement of Halim et al. (2021) that in the cultivation of vaname shrimp, there are still several failures due to poor water quality, especially in intensive ponds, which is caused by high stocking densities and feeding large amounts of shrimp, which will leave food residue which will later become a source of organic material.

Water quality plays a role in the condition and performance of cultivated biota, in this case vaname shrimp (Gao et al., 2016). It is reported that significant fluctuations in water quality can be dangerous for shrimp cultivation (Rahman et al., 2015), because it can cause shrimp to become stressed and decomposition of organic matter due to feed at the bottom of the water will decrease (Supriatna et al., 2017), besides that according

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to Ariadi et al. (2019), that stressed shrimp are very easily attacked by disease and die so that the mortality rate in cultivation will increase. Waste from cultivation inputs will increase as shrimp biomass increases and the age of shrimp cultivation (Brown et al, 2015). In addition, Fatimah et al. (2018) explained that growing shrimp cultivation activities can cause pollution in wastewater bodies. Waste from intensive cultivation is rich in organic materials and chemical compounds originating from shrimp feed and feces, so it has the potential to pollute surrounding water bodies (Tangguda and Prasetia, 2019). According to Arfiati et al. (2020), shrimp cultivation wastewater after the end of the rearing period has a high total organic matter (TOM) content of up to 87.74 mg/L, while the level of organic matter is safe for the aquatic environment according to Supriyantini, et al. (2017), namely ≤ 30 mg/l. Good water quality management plays an important role in increasing pond productivity and providing a safe and healthy environment (Samadan, 2018).

Changes in water quality have an impact on plankton community structure (Widianingsih and Suryono, 2021). Changes in plankton communities occur according to the conditions of the aquatic environment. Environmental conditions influence changes in the composition, type, and number of plankton which are related to the trophic structure of waters by phytoplankton groups. Plankton communities are dynamic so that one species or genus is dominant over other species or genera in a relatively short time interval. The existence of important phytoplankton in pond waters needs to be managed properly through water quality monitoring. Phytoplankton can produce dissolved oxygen which can be utilized by bacteria to absorb compounds that are very dangerous for shrimp such as ammonia and nitrite. Zooplankton is useful in regenerating nitrogen in waters through its decomposition process so it is useful for bacteria and phytoplankton productivity. Plankton in intensive cultivation ponds can be useful in reducing water brightness because high brightness in ponds will have an impact on disrupting shrimp activity (Utojo, 2015).

Based on this description, it is necessary to carry out research on the dynamics of water quality, both physics, chemistry and biology (plankton) in intensive cultivation media for vaname shrimp (Litopenaeus vannamei) as well as at cultivation waste disposal sites in the coastal areas of Ujungpangkah District, Gresik Regency so that quality management can be carried out. good and appropriate water, in order to increase the productivity of vannamei shrimp and the health of the aquatic environment around the pond. The aim of the research is to determine the dynamics of the physical, chemical and biological quality of cultivation media water and the disposal of vaname shrimp cultivation waste in Ujungpangkah District, Gresik Regency.

Method

This research was conducted in January 2023 for 3 weeks, using a survey method. Sampling is done once a week. Water quality parameters were observed at 3 cultivation water flow points, namely reservoirs (water storage preparation for cultivation), cultivation ponds, and cultivation waste disposal sites. Sampling was carried out at vaname shrimp cultivation ponds in the Coastal Area of Ujungpangkah District, Gresik Regency, and measurements of water chemical parameters were carried out at the Sumberpasir Freshwater Fisheries Laboratory, Malang Regency. The sampling location can be seen in Figure 1.

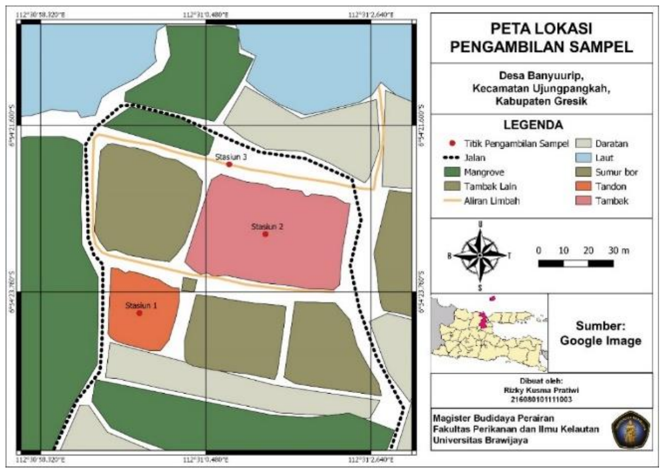


Figure 1. Map of sampling locations

This research method was carried out using a descriptive survey method and purposive sampling. The parameters observed include physical and chemical water quality parameters, as well as biological parameters in the form of plankton (phytoplankton and zooplankton).

Water Quality Analysis

Water quality parameters in this study were measured once a week, consisting of in-situ water quality parameters consisting of temperature and dissolved oxygen using a Lutron PDO-520 DO meter, salinity using an AR8012 salinometer, pH using a Merck pH paper and carbon dioxide (CO2) using H2CO3 titration. . Water quality measurements were carried out ex-situ, namely nitrate, orthophosphate and ammonia using a spectrophotometer, total organic matter parameters using the KMnO4 titration method were carried out at the Sumber Pasir Freshwater Fisheries UPT Laboratory.

Water Plankton Sampling

Water plankton samples are taken compositely every 7 days because it is adjusted to the plankton life cycle of 7 – 14 days. 30 liters of pond water is filtered, using plankton net number 25. The filtered plankton is placed in a 60 ml sample bottle, 1% lugol (0.6 ml) and 4% formalin (2.4 ml) are added and the sample bottle is marked with a label, then stored in a cool box and taken to the laboratory for identification and counting.

Plankton Analysis

The plankton community structure in a body of water can be seen from the plankton abundance, diversity index, uniformity index, and dominance index. Calculation of aquatic plankton abundance uses the modified Luckey Drop formula (Herawati et al., 2019), diversity index (Shannon and Weaver, 1949), uniformity index (Odum, 1971), and dominance index (Simpson, 1949).

Data Analysis

Water quality data is presented in tables and graphs, and analyzed descriptively. The results were compared with previous related and similar studies.

Result and Discussion

Physical and Chemical Quality of Water

Water quality is an important aspect of vannamei shrimp cultivation activities. Vannamei shrimp can grow optimally and live properly in environmental conditions or water quality that meets the requirements. Good water quality plays a role in determining the success of vannamei shrimp cultivation. So, good and appropriate water quality management efforts are needed. Water quality parameters that are important to monitor include temperature, salinity, pH, dissolved oxygen (O_2), carbon dioxide (CO_2), nitrate, orthophosphate, ammonia, and total organic matter (BOT) in rearing vaname shrimp because they are related to the shrimp's body metabolic processes such as activity. foraging, digestion, and growth. The results of water quality measurements in this study are seen in Table 1.

Table 1. Data on Water Quality Results

Water Quality Parameter	Min-max (average ± SD)		
	Water container	Fishpond	Waste
Temperature	27,2 – 29,1 (28,23 ± 0,78)	28,6 – 29,4 (28,93 ± 0,33)	28,4 – 31 (29,43 ± 1,12)
Salinity	23	22 - 23 (22,67 ± 0,47)	20 – 23 (22 ± 1,41)
pH	8	7 – 8 (7,68 ± 0,47)	8
Dissolved Oxygen	6,3 – 7,8 (6,87 ± 0,67)	6,4 – 8,1 (7,43 ± 0,74)	1,9 – 3,6 (2,6 ± 0,73)
Carbon Dioxide	0	0 – 39,95 (20 ± 16,3)	0 – 32,82 (19 ± 13,89)
Nitrate	0,182 – 0,303 (0,229 ± 0,053)	0,589 – 0,644 (0,621 ± 0,023)	0,479 – 1,003 (0,745 ± 0,214)
Orthofphosphate	0,013 – 0,073 (0,033 ± 0,028)	0,097 – 0,407 (0,231 ± 0,130)	0,164 – 0,293 (0,234 ± 0,053)
Ammonia	0,056 – 0,094 (0,081 ± 0,018)	0,161 – 1,105 (0,483 ± 0,440)	0,105 – 0,189 (0,155 ± 0,036)
Total Organic Matter	6,32 – 73,31 (36,23 ± 27,81)	3,79 – 79,63 (46,35 ± 31,64)	51,82 – 88,48 (64,89 ± 16,71)

Temperature

In this study, the average result was that the highest temperature was at the waste disposal site, namely 29.43^{o}C, while the lowest temperature was in the drill tank water, that is 28.23^{o}C. As DOC increases, the temperature in this study decreases but is still stable. This is because the decomposition process of organic materials is also increasing, giving rise to high temperatures. According to Yuningsih et al. (2014), in warm waters, it can be triggered by the decomposition process of organic material by microorganisms. Apart from that, this is because, during the cultivation process, the weather is not very hot or tends to be cloudy (Halim et al., 2021). The temperature in this study was still within the tolerance limit for shrimp growth, namely around 27 – 30^{o}C. This is in accordance with Wang et al.

(2020), that the optimal temperature for growing vannamei shrimp ranges between 28-30°C

Salinity

In this research, the salinity results were more stable, ranging from 20-23 ppt. The observation point that obtained the lowest salinity was in pond water and the highest was in reservoir water. The high salinity in the reservoir is caused by evaporation in the water column. According to Annisa (2021), salinity is the level of saltiness or dissolved salt content in water. The salinity results obtained from the research are classified as optimal. This is in accordance with the statement (Anita et al., 2017) that the optimal salinity value for cultivating vannamei shrimp so that they can grow well is at a salinity of 15-25 ppt, even shrimp can still survive at a salinity of 5 ppt.

pH

In this study, the pH results obtained ranged from 7-8. pH fluctuations did not occur significantly between observation points because one observation point was located in a close area. pH has a big influence on the life of organisms because pH is used as a component of whether water is good or bad. According to Elfidasari et al. (2017), waters generally have a certain range for the life of aquatic organisms, which is usually at neutral values or at weak acid and weak base values, namely, 6.5 - 8.5.

Dissolved Oxygen

Dissolved oxygen ranges from 1.9 – 8.1 mg/l. The lowest average dissolved oxygen results were in waste, namely 2.6 mg/l, while the highest average was in ponds with levels of 7.43 mg/l. Waste has low oxygen because in the waste there is decomposition of organic material (putrefaction). This is in accordance with the statement from Yuningsih, et al. (2014) that the process of decomposing organic matter can cause dissolved oxygen levels to decrease to a value of 0. Dissolved oxygen is still in the optimal range of 3.8-7.1 ppm for shrimp cultivation (Putri et al., 2020). The dynamics of water quality parameters, dissolved oxygen, can be seen in Figure 2.

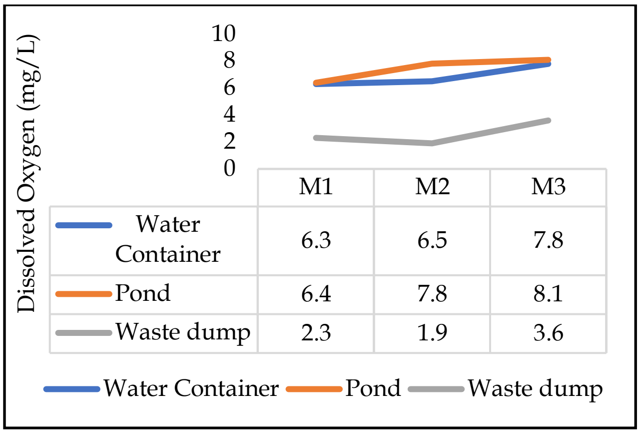


Figure 2. Dissolved Oxygen Measurement Graph

Carbon Dioxide

Carbon dioxide levels in this study ranged from 0–39.95 mg/l. The lowest average carbon dioxide levels were in ponds with levels of 0 mg/l, while the highest average carbon dioxide levels were in ponds, namely 20 mg/l. The carbon dioxide level was 0, possibly because the sampling was carried out during the day so that the photosynthesis process was taking place (carbon dioxide was utilized optimally by phytoplankton). Asis et al., (2017) explained that at high concentrations (> 10 mg/l), carbon dioxide can be toxic because the presence of CO2 in the blood can suppress fish respiratory activity and inhibit the binding of oxygen by hemoglobin. The dynamics of water quality carbon dioxide parameters can be seen in Figure 3.

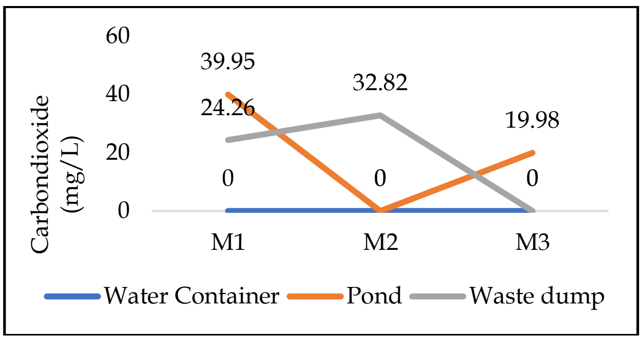


Figure 2. Carbon Dioxide Measurement Chart

Nitrate

Nitrate levels ranged from 0.064-1.002 mg/l. The average nitrate level was 0.229 mg/l (lowest) in the reservoir, while the highest average nitrate level was in the waste, namely 0.745 mg/l. Waste has high nitrate levels due to the high levels of nutrients originating from the decomposition of compounds that occur in waste disposal sites. Nitrate in water is a macronutrient that controls primary productivity in euphotic areas. The measured nitrate concentration is below the quality standard set for waters of 10 mg/l., whereas according to Minister of Maritime Affairs and Fisheries

Regulation No. 75 of 2016 concerning the maintenance of vaname shrimp, good nitrate for water sources and the maintenance of vaname shrimp is 0.5 mg/l. The dynamics of water quality parameters, nitrate, can be seen in Figure 4.

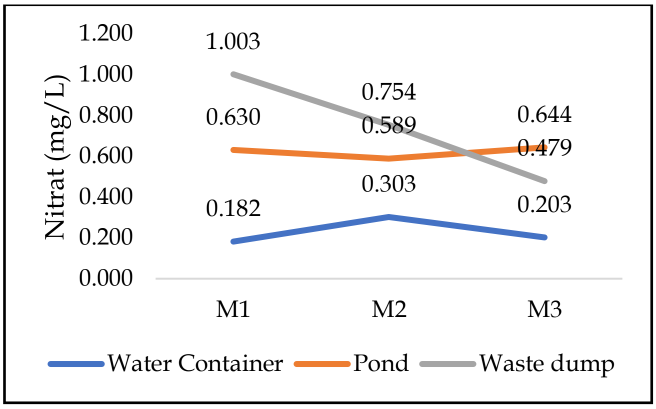


Figure 3. Nitrate Measurement Chart

Orthophosphate

Orthophosphate is the simplest phosphate compound and can be directly utilized by phytoplankton. The results showed that orthophosphate ranged between 0.001-0.407 mg/l. The lowest average (0.033 mg/l) was in the reservoir, while the highest average (0.234 mg/l) was in the waste disposal. Cultivation waste is rich in nutrients due to the decomposition of organic compounds, so the orthophosphate content is high.

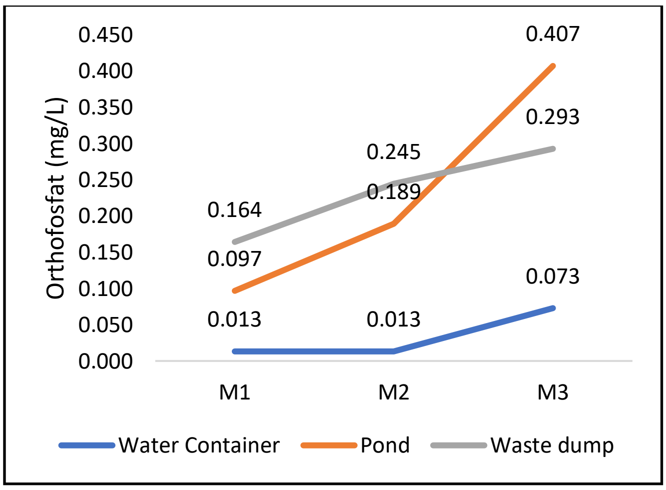


Figure 4. Chart Measurement Orthophosphate

According to Akbarurrasyid et al. (2022), the optimal phosphate concentration for phytoplankton growth ranges from 0.27 – 5.51 ppm, and phosphate content < 0.02 ppm is a limiting factor for phytoplankton growth. The dynamics of water quality orthophosphate parameters can be seen in Figure 5

Ammonia

Ujungpangkah station ammonia ranges between 0.001- 0.105 mg/l. The average results show that the highest ammonia was in ponds with levels of 0.483 mg/l and the lowest ammonia values were in water sources with levels of 0.005 mg/l. The dynamics of water quality parameters for ammonia can be seen in Figure 6. It is similar to ponds in Probolinggo, where ponds receive input from organic compounds which are a source of ammonia that comes from the metabolism of cultivated biota. The ammonia range of 0.001-0.162 mg/l is optimal for rearing vaname shrimp and for plankton growth. Ammonia levels are still safe for aquatic organisms, namely 0.01-0.16 mg/L (Mirna et al., 2020).

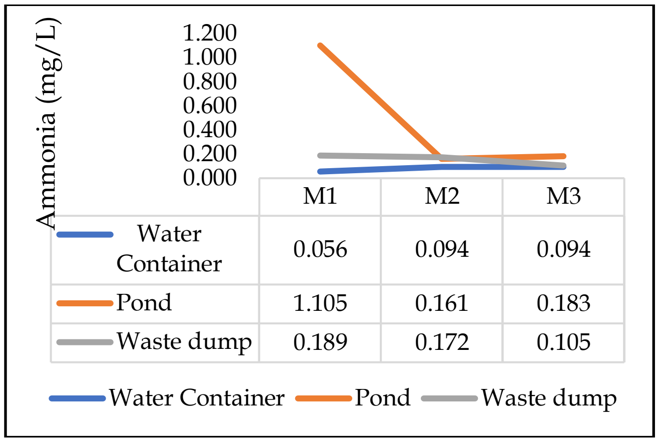


Figure 5. Ammonia Measurement Chart

Total Organic Matter (BOT)

The results obtained for organic materials ranged from 0-88.48 mg/l. The lowest average TOM value was in water reservoirs, namely 36.23 mg/l, while the highest was in waste, namely 64.89 mg/l. Waste gets a high value because waste is a dumping ground for cultivation residues which contain a lot of organic pollutant loads originating from shrimp carcasses, shrimp feces and unused feed residue (Ariadi et al., 2021). These organic compounds are what cause high levels of organic waste. Organic matter levels that are too high will have an impact on reducing oxygen carrying capacity due to increasingly intense decomposition processes (< 30 mg/L) (Supriyantini et al., 2017). The dynamics of water quality BOT parameters can be seen in Figure 7.

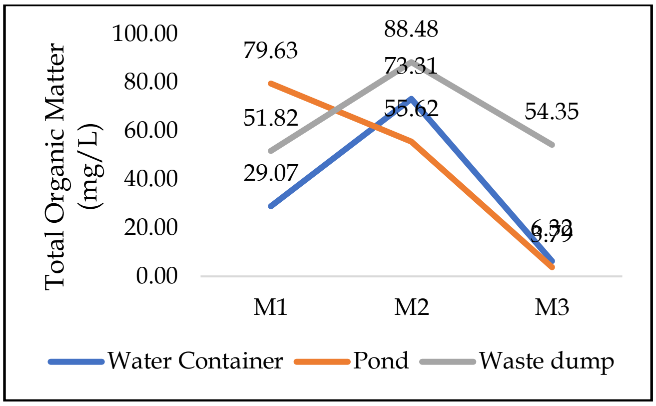


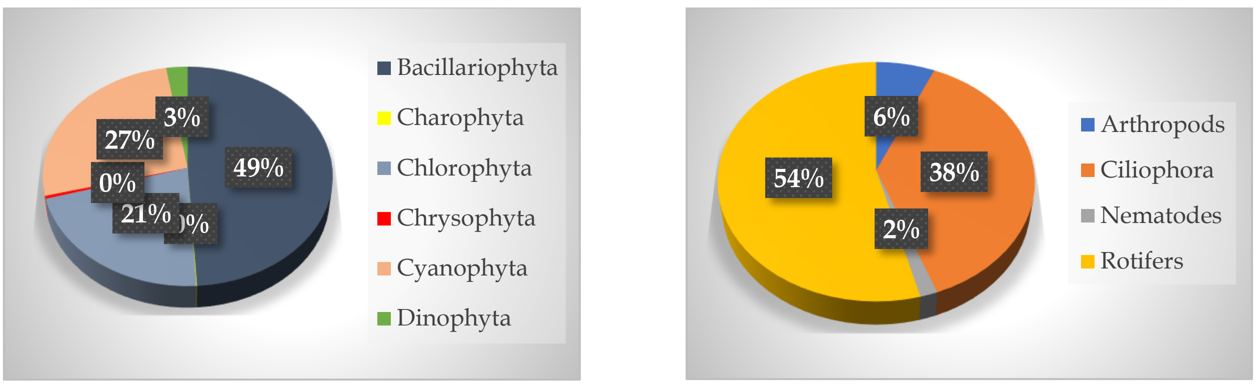
Figure 7. Total Organic Matter Measurement Chart

Biological Quality of Water

Plankton Community Structure

The results of phytoplankton observations at 3 sampling points, there were 6 phyla and 27 genera, namely from the Bacillariophyta film consisting of 18 genera, namely Amphora, Amphiprora, Chaetoceros, Cocconeis, Coscinodiscus, Cyclotella, Cylindrotheca, Cymbella, Diploneis, Entomoneis, Gyrosigma, Mellosira, Navicula, Nitzschia, Pinnularia, Skeletonema, Stauronella and Thalassiosira, Phylum Charophyta consists of 1 genus, namely Netrium, Phylum Chlorophyta consists of 1 genus, namely Chlorella, Phylum Chrysophyta consists of 1 genus, namely Streptotecha, Phylum Cyanophyta consists of 3 genera, namely Aphanocapsa, Chroococus and Merismopedia, The Dinophyta phylum consists of 3 genera, namely Ceratium, Gymnodinium and Protoperidinium. On average, the phytoplankton phylum with the highest presence at the 4 observation points came from the Phylum Bacillariophyta at 49%. Bacillariophyta is often found in brackish waters and that is able to adapt to environmental changes, including the input of wastewater into ponds (Yuliana and Mutmainnah, 2019).

The results of zooplankton observations at 3 sampling points contained 4 phyla and 7 genera, namely the Arthropoda Phylum consisting of 1 genus, namely Nauplius, the Ciliophora Phylum consisting of 4 genera, namely Euplotes, Halteria, Strombidium and Zoothamnium, the Nematoda Phylum consisting of 1 genus, namely Mononchus, the Rotifera Phylum consisting of from 2 genera, namely Cephalodella and Brachionus. On average, the zooplankton phylum with the highest presence at the 4 observation points came from the Phylum Rotifera at 54%. Rotifers are often found because they like waters that contain organic material (Khaeriyah, 2013). The average composition of phytoplankton and zooplankton can be seen in Figure 8.



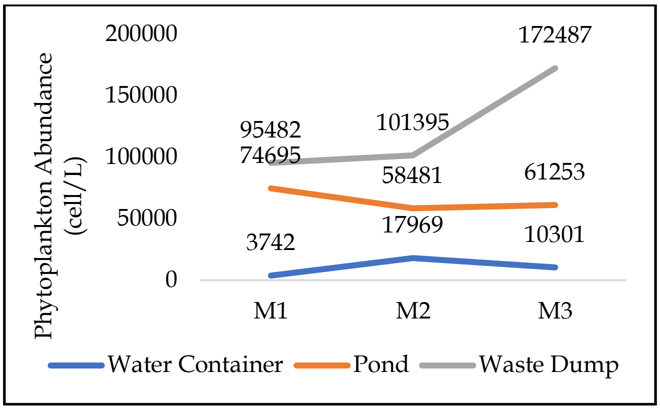
(a) (b)

Figure 6. Average composition, A) Phytoplankton, B) Zooplankton

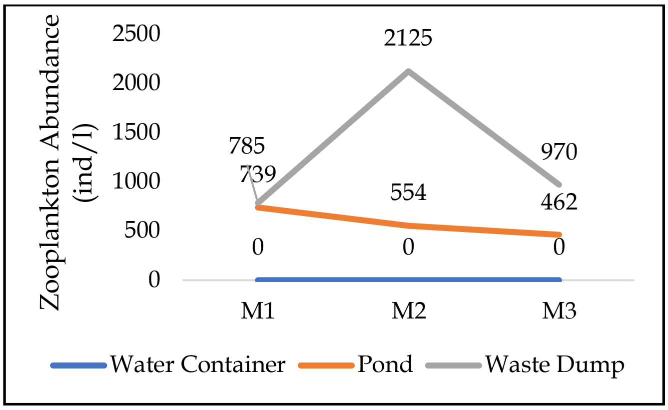
Plankton Abondance

In this study, the results obtained for phytoplankton abundance ranged from 1,109 – 172,487 cells/l. The highest average abundance was in waste disposal, while the lowest average abundance was in water reservoirs. The plankton abundance graph is presented in Figure 9

The highest average abundance during observations came from the Bacillariophyta phylum, namely 294,022 cells/l, while the lowest average abundance came from the Charophyta phylum, namely 416 cells/L. Zooplankton ranged from 462–2,125 ind/l. The highest average abundance of zooplankton was in wastewater (785-2125 ind/l), while the lowest average abundance was in ponds (462-739 ind/l). No zooplankton were found in the water tank. The highest average abundance during observations came from the Phylum Rotifera, namely 3049 ind/l, while the lowest average abundance came from the phylum Nematoda, namely 92 ind/l. Waste has a high abundance value due to high nutrient elements, thus triggering a high abundance of plankton.



(a)



(b)

Figure 7. Abundance of plankton, A) Phytoplankton, B) Zooplankton

Plankton Biology Index

The results obtained for the phytoplankton diversity index ranged from 0.94 - 2.04 in the low to medium category, while zooplankton ranged from 0 - 2.12 in the low to medium category. According to the following statement, the H' value between 1 < H' < 3 means plankton diversity is moderate, whereas if H' > 3 means high diversity (Aini et al., 2018). If the plankton diversity index value is in the medium category, then the waters have been polluted by waste surrounding the waters (Djunaidah et al., 2017). According to Enawgaw and Wagaw (2023), plankton species diversity is an excellent biological indicator for determining environmental health.

The results obtained for the phytoplankton uniformity index ranged from 0.40 to 0.88 in the medium to high category, while zooplankton ranged from 0 - 1 in the low to high category. If the uniformity index value (e) ranges between 0 – 1, then the uniformity is low. If the (e) value is between 0.4 – 0.6, then the uniformity is moderate, whereas if it is 0.6 – 1.0, it means high uniformity. A low uniformity index value means that the distribution of individuals of the same type is uneven and there are species that dominate in those waters (Djunaidah et al., 2017).

The phytoplankton and zooplankton dominance index in this study showed low to high dominance with values of 0.30 - 0.65 and 0 - 0.69 respectively. If the dominance index value is in the range 0 < D < 0.5, then there is no type of plankton that dominates in the waters. Meanwhile, in the range 0.5 < D < 1, there are types of plankton that dominate in the waters (Munthe et al., 2012). Phytoplankton is dominated by the genus Chlorella, from the phylum Chlorophyta. The dominant zooplankton is the genus Brachionus from the phylum Rotifera. The Phylum Rotifera is often found because it can adapt to waters containing high levels of organic matter (Khaeriyah, 2013).

Conclusion

Measurements of the physical and chemical quality of water carried out in reservoirs, ponds, and disposal of vaname shrimp cultivation waste have a pattern of changes that fluctuate but are relatively the same and stable every day. All of these water quality parameters show a pattern of change that is quite good for the growth of vaname shrimp, but in waste disposal, the parameters for nitrate, phosphate, ammonia, and TOM are above the quality standards. The biological quality of the water shows that plankton is in high abundance in waste disposal, with phytoplankton coming from the phylum Bacillariophyta (49%), while zooplankton comes from the phylum Rotifera (54%).

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Author Contributions
Conceptualization, Rizky Kusma Pratiwi and Abdul. Rahem Faqih.; Methodology, Mohammad Mahmudi; Software, Mohammad Mahmudi; Validation, Mohammad Mahmudi., Abdul Rahem Faqih and Diana Arfiati.; Formal analysis, Rizky Kusma Pratiwi; investigation, Mohammad Mahmudi; resources, Diana Arfiati; data curation, Rizky Kusma Pratiwi; writing—original draft preparation, Rizky Kusma Pratiwi; writing—review and editing, Rizky Kusma Pratiwi; visualization, Rizky Kusma Pratiwi; supervision, Mohammad Mahmudi; project administration, Abdul Rahem Faqih; funding acquisition, Diana Arfiati.

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Conflicts of Interest
The authors declare no conflict of interest

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