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Community structure of plankton in Whiteleg shrimp, *Litopenaeus vannamei* (Boone, 1931), pond ecosystem

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Abstract. *Inayah ZN, Musa M, Arfiati D, Pratiwi RK. 2023. Community structure of plankton in Whiteleg shrimp,* Litopenaeus vannamei *(Boone, 1931), pond ecosystem. Biodiversitas 24: 4008-4016.* Plankton in shrimp farming can be used to maintain the balance of the pond ecosystem. The purpose of this study is to analyze the plankton community in the whiteleg *Litopenaeus vannamei* shrimp pond ecosystem. This research was conducted in January-April 2023 and it is a descriptive study using a survey method. The research location is in an intensive whiteleg shrimp aquaculture pond in Probolinggo, East Java. The results showed that the plankton found in whiteleg shrimp ponds consisted of phytoplankton and zooplankton. The phytoplankton found consisted of 4 phyla with 18 genera, while zooplankton consisted of 3 phyla with 8 genera. Phytoplankton phylum consists of Bacillariophyta, Chlorophyta, Cyanophyta and Dinophyta, while zooplankton consists of Arthropoda, Ciliophora and Rotifera phyla. The highest total abundance of phytoplankton was 8,192,370 cells/L, while zooplankton was 55,121 cells/L. The highest abundance of phytoplankton was *Oocystis* (Chlorophyta) of 8,094,015 cells/L, while zooplankton, namely *Euplotes* (Ciliophora) was 40,154 ind/L. The index of diversity, uniformity and dominance of phytoplankton ranged from 0.05-1.76, 0.02-0.65 and 0.38-0.99, respectively. Zooplankton has diversity, uniformity and dominance indices ranging from 0-2.03, 0-1 and 0.27-1, respectively.

Keywords: Cultivation, phytoplankton, pond, whiteleg shrimp, zooplankton

INTRODUCTION

Whiteleg shrimp *Litopenaeus vannamei* is one of the prime commodities that is commonly cultivated in Indonesia. This shrimp is a native species from Central and South America (Kongchum et al. 2022), hich was first introduced to Indonesia in 2001 based on the Decree of the Minister of Marine and Fisheries Affairs of the Republic of Indonesia No. 41/2001 (Wijayanto et al. 2017). This particular shrimp species has advantages compared to other shrimp commodities including fast growth, more resistance to disease, and high economic value (An et al. 2020). The primacy possessed by whiteleg shrimp compared to other shrimps has fueled the passion for cultivating this fishery export commodity to grow. According to Mustafa et al. (2023), the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia has targeted an increasing export value and production of shrimp by 250% in 2024. Therefore, a strategy is needed to develop whiteleg shrimp cultivation which can increase production but does not harm the aquatic environment.

One of the organisms that are in the shrimp culture environment and can be utilized during the cultivation process is plankton. Plankton can be used as natural feed in shrimp farming (Tugiyono et al. 2017), it can be used in the development of shrimp farming as well as to increase production. The presence of live feed increases the efficiency of artificial feed and optimizes the conversion rate of shrimp farming (Soeprapto et al. 2023). Besides being used sas natural food, plankton is also used as a bioindicator of water quality. The plankton community is very sensitive to changes and dynamics of water quality, especially nutrients such as nitrate and phosphate (Muhtadi et al. 2020).

Plankton are organisms that float or hover in the waters, relatively passive movements so they are always carried away by water currents (Vesensia et al. 2021). Plankton are grouped into two, namely phytoplankton and zooplankton. Phytoplankton or commonly called vegetable plankton are plants found in waters with microscopic sizes. Phytoplankton can be found throughout the mass of water from the surface to depth with sufficient light. Phytoplankton can carry out photosynthesis because they have chlorophyll pigments. Zooplankton can be called animal plankton, larger than phytoplankton (Hendrajat and Sahrijanna 2018). Plankton can be used as natural food and has a significant impact on the growth of aquatic organisms such as fish, crabs, shrimp and lobsters (Masithah et al. 2023).

According to Kamilia et al. (2021), phytoplankton in shrimp ponds is used as natural food and maintains the balance of the pond ecosystem. The genus of phytoplankton that is commonly found in shrimp ponds comes from the class Chlorophyceae (*Chlorella*) and class Bacillariophyceae (*Cyclotella*). High levels of harmful phytoplankton such as Cyanophyceae can lead to lower shrimp survival rates. Cyanophyceae are harmful phytoplankton because of their ability to produce secondary metabolites in the form of toxins that are harmful to shrimp, such as microcystins (MCYs), anatoxin-a, anatoxin-a(s), cylindrospermopsin (CYN), and saxitoxin (STX). This poison has specific target organs, causing organ damage to death when present in aquatic organisms at high levels. Conroy et al. (2017) explained that the presence of phytoplankton is influenced by various biotic (zooplankton) and abiotic factors (temperature, light intensity and nutrients). In general by Kunlapapuk et al. (2021), nutrients in ponds have increased with increasing cultivation time. The accumulation of nutrients in ponds can be utilized by phytoplankton for their growth.

Zooplankton is one of the pillars of the aquatic bioecosystem because of its position as the first consumer in the food chain. The role of zooplankton is to link primary producers with the next trophic level which is also the controller of primary production (phytoplankton) (Naselli-Flores and Padisák 2022). Based on Nguyen et al. (2022), zooplankton that is often found in whiteleg shrimp ponds include Protozoa, Rotifera and Copepoda. Protozoa are parasitic, generally found in conditions of unstable water quality, especially temperature, such as *Zoothamnium* sp. which develop more rapidly at temperatures >30°C.

Changes in the composition of plankton in the cultivation environment can indicate changes in the quality of the pond environment which can have an impact on the balance of the pond ecosystem. The importance of the role of plankton in the whiteleg shrimp aquaculture pond is the basis of this research. The purpose of this study is to analyze the plankton community that makes up the whiteleg shrimp pond ecosystem. Profiling the plankton community structure in this study may also reveal food potential for shrimp.

MATERIALS AND METHODS

Time and location of research

This research was conducted in January-April 2023. The research location was in the whiteleg shrimp intensive pond belonging to the Faculty of Fisheries and Marine Sciences, Brawijaya University in the Brackish and Sea Water Fisheries Laboratory, Mangunharjo Village, Mayangan District, Probolinggo City, East Java Province, Indonesia. The sampling map can be seen in Figure 1. Sampling is carried out every week for one cycle of whiteleg shrimp cultivation. Observation of samples was carried out at the Sumberpasir Freshwater Fisheries Laboratory, Malang Regency. The distance between the sampling location and the laboratory is ±115 km with a travel time of ±120 minutes.

Sampling procedure

Plankton sampling was carried out at a depth of 0-0.5 meters. Retrieval of plankton using a 5-liter bucket with 5 repetitions (total sample volume of 25 liters). Water was filtered using a 25 µm plankton net. Water is collected using a plastic bottle with a volume of 33 mL. The filtered plankton in the container bottle is transferred to a larger volume plastic bottle (60 mL) to add 1% Lugol's solution and 2% formalin as a preservative, then the bottle was closed and labeled. Preservation of phytoplankton primarily uses Lugol's solution while preservation of zooplankton uses formalin as much as 1-2% concentration. It is worth noting that zooplankton cannot tolerate formalin even in small amounts (Celewicz-Gołdyn and Kuczyńska-Kippen 2017; Fernandes et al. 2019; Sano et al. 2022). The samples were then labeled and stored in a cool box filled with ice to maintain a 4°C temperature inside the box and the samples were taken to the laboratory for analysis.

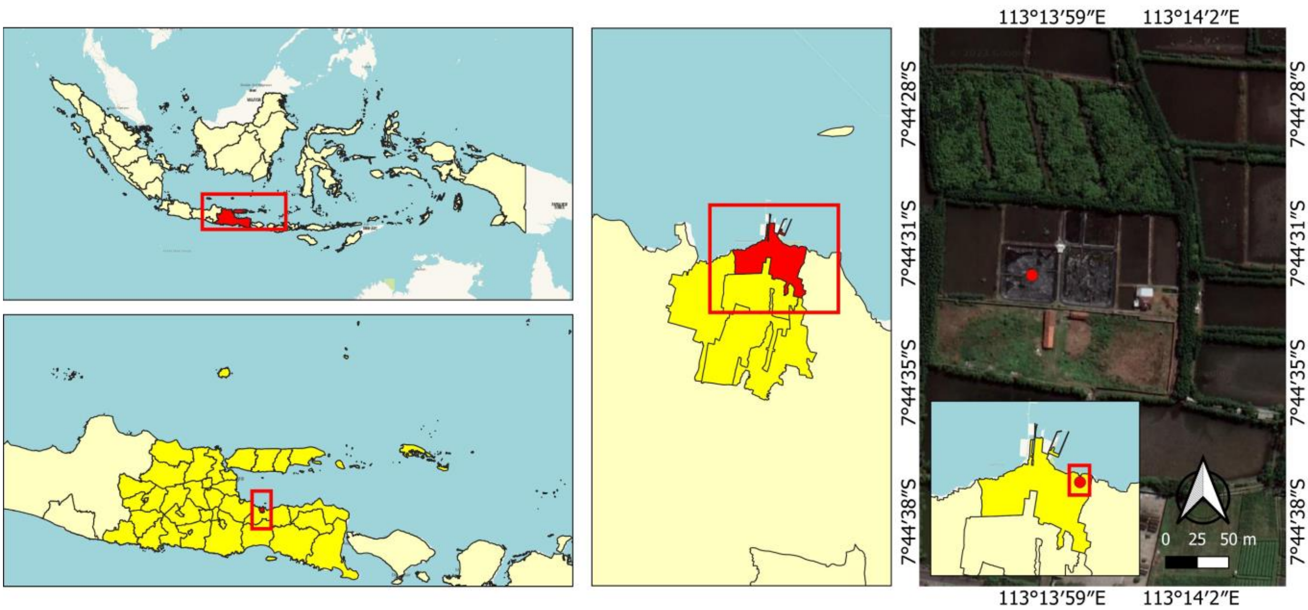

Figure 1. Location of the whiteleg shrimp pond study in the Brackish and Sea Water Fisheries Laboratory, Mangunharjo Village, Mayangan Sub-district, Probolinggo City, East Java Province, Indonesia

Observation and identification of plankton

Plankton observations were carried out using a binocular microscope. The plankton samples that have been obtained are observed under a microscope to determine their species composition. The plankton sample in the bottle was shaken to homogenization. One drop of aliquot sample was taken using a dropper pipette and placed on a glass slide and covered using a cover slip. The cover slip was slowly put into place to avoid the proliferation of air bubbles that may affect visual observation. The plankton was then identified and counted under a microscope with an objective lens magnification of 40x (Merz et al. 2021). Identification of plankton using the identification guide of Davis (1955) and Conway et al. (2003). Identification of plankton was carried out up to the genus level only.

Data analysis

Data analysis was performed using data analysis tool in the Microsoft Excel 2016. Plankton data analysis included abundance, diversity index, uniformity index and dominance index.

Plankton abundance

The abundance of aquatic plankton was calculated using the modified Lackey Drop formula (Lackey 1938; Junaidi et al. 2018), as follows:

$$N = \frac{T \times V}{L \times v \times p \times W} \times n$$

Where:
N: Plankton abundance (cell/l atau ind/L)
n: Number of plankton found
T: Cover glass area (mm^2)
V: The Volume of the water sample (mL)
L: Field of View area (mm^2)
v: The Observed volume of water (mL)
p: Number of Field of View
W: Filtered water volume (L)

Diversity index

The plankton diversity index was calculated using the Shannon-Weaver diversity index (Shannon dan Weaver 1949; Margalef 1978; Odum 1971). The diversity index formula is as follows:

$$H = -\sum_{i=1}^{S} pi \, log_2 \, pi \; ; \quad \text{Which: } pi = \frac{n_i}{N}$$

Where:
H: Diversity Index
n_i: Number of individuals-i
N: Total number of individuals in the sample
The diversity index criteria are as follows:
H < 1 : low diversity
1 < *H* < 3 : moderate diversity
H > 3 : high diversity

Uniformity index

The uniformity index shows the evenness of the species (Odum 1971). The uniformity index was calculated using the following formula:

$$e = \frac{H}{H_{max}}; \text{ Which: } H_{max} = log_2 \, S$$

Where:
e: Uniformity index
H: Diversity index
S: Number of species

The uniformity index value (*e*) ranges from 0-1. Uniformity index values 0-0.4 indicate low uniformity, values 0.4-0.6 indicate moderate uniformity and values 0.6-1.0 indicate high uniformity.

Dominance index

The dominance index is calculated to determine the type of plankton that dominates. The dominance index uses the Simpson dominance index formula (Simpson 1949; Magurran 1955; Margalef 1978; Odum 1971), as follows:

$$C = \sum_{i=1}^{s} pi^2 \; ; \quad \text{Which: } pi = \frac{n_i}{N}$$

Where:
C: Dominance index
ni: Number of individuals-i
N: Total number of individuals in the sample

The dominance index value ranges from 0 to 1. If the C value is close to 0, it means that there are no dominant species and conversely, a C value that is closer to 1 means that there is a dominant species. The greater the dominance index value indicates that the diversity is low.

RESULTS AND DISCUSSION

The results of observing plankton in the pond during whiteleg shrimp cultivation consisted of phytoplankton and zooplankton (Figure 2). The composition of plankton in whiteleg shrimp ponds during cultivation as a whole was higher in types of phytoplankton than zooplankton. Phytoplankton composition during cultivation ranged from 91.52 - 99.97%, while zooplankton ranged from 0.03 - 8.48%.

The existence of phytoplankton in an ecosystem is generally higher than zooplankton because of the faster growth of phytoplankton. Higher phytoplankton also indicates a stable ecosystem due to the higher number of primary producers than consumers, thus indicating high water productivity (Vallina et al. 2017; Otero et al. 2020).

The total abundance of phytoplankton and zooplankton can be seen in Figure 3. The highest total abundance of phytoplankton found at the end of cultivation (week-14) was 8,192,370 cells/L, while the highest total abundance of zooplankton was at week-7 of 55,121 cells/L. The abundance of plankton found during cultivation has fluctuated. The low value of abundance in general is accompanied by an increase in the abundance of zooplankton. This is due to predation by zooplankton. Factors that affect the abundance of phytoplankton are nutrients, light and predation by producers (zooplankton and shrimp) (Rasconi et al. 2017; Wijaya dan Elfiansyah 2022; Musa et al. 2023).

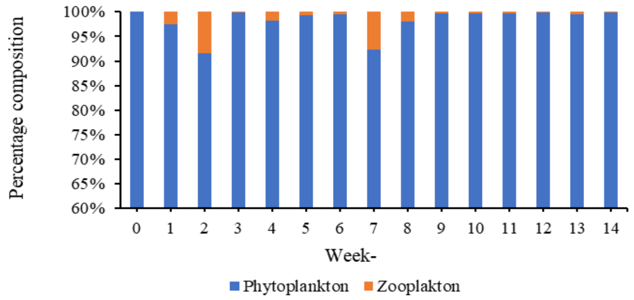

Figure 2. Weekly percent composition of phytoplankton and zooplankton in the whiteleg shrimp pond ecosystem

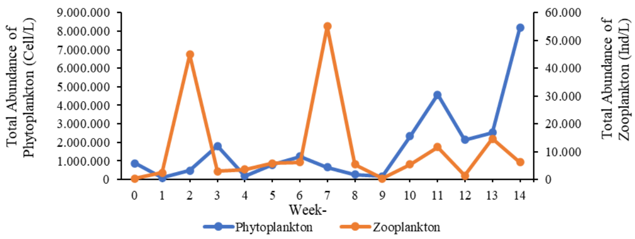

Figure 3. Total abundance of plankton

The results of plankton abundance indicate that aquaculture ponds are included in mesotrophic to eutrophic conditions. According to Vesensia et al. (2021), oligotrophic water conditions are waters that have low fertility and have an abundance of phytoplankton of 0-2,000 cells/L and zooplankton of 1 ind/L. Waters with medium fertility having an abundance of 2,000-5,000 cells/L for phytoplankton and 1-500 ind/L for zooplankton are called mesotrophic. Eutrophic are waters that have high fertility with an abundance of >15000 cells/L for phytoplankton and >500 ind/L for zooplankton.

Mesotropic conditions indicate moderate pond fertility, while eutrophic conditions indicate fertile waters. In general, mesotrophic to eutrophic conditions are good conditions for cultivation. However, eutrophic conditions must be monitored so that eutrophication of the waters does not occur. Eutrophication conditions in ponds are not good for cultured shrimp. This is because waters that experience eutrophication will result in low levels of dissolved oxygen in ponds (Astuti et al. 2022; Briddon et al. 2023). Plankton found in whiteleg shrimp ponds from this study can be seen in Figure 4.

Phytoplankton

Phytoplankton found in whiteleg shrimp ponds during cultivation consists of 4 phyla with 18 genera. The phyla are Bacillariophyta, Chlorophyta, Cyanophyta and Dinophyta. The composition of phytoplankton based on phyla found during whiteleg shrimp cultivation can be seen in Figure 5. The highest percentage of composition is based on phyla in general, namely the Chlorophyta phylum which reached 99.67%. The highest percentage of phylum Bacillariophyta reached 99.79%, but only at the beginning of cultivation, while the highest percentage of phylum Cyanophyta was 65.25% in the week-12. Phylum Dinophyta had the lowest percentage among other phyla, where the highest percentage was only 1.14% in week-9. The highest percentage of phytoplankton composition at the beginning of cultivation was Bacillariophyta but was replaced by Chlorophyta as time went on. Phylum Cyanophyta increased from the 9th week and peaked at the week-12, but decreased again.

This research is following the statement by Qiao et al. (2020), that Bacillariophyta, Chlorophyta and Cyanophyta are groups of phytoplankton that are often found and dominate in ponds. Bacillariophyta is a phylum that has the highest abundance reaching 98% at the beginning of cultivation and decreasing with increasing cultivation time. Chlorophyta phylum experienced an increase in mid-cultivation. The next phase of Bacillariophyta will appear again, but the phylum Cyanophyta will be more abundant at the end of its peak cultivation reaching 44.77% of the total percentage.

The abundance of phytoplankton is based on the highest phylum, namely the Chlorophyta phylum, where the highest abundance in the 14th week was 8,164,978 cells/L. Phylum Bacillariophyta had the highest abundance in week 0 of cultivation, namely 867,076 cells/L. The highest abundance of phylum Cyanophyta was at week 12 of 1,400,814 cells/L, while Dinophyta at week 10 was 13,506 cells/L. A graph of the abundance of phytoplankton in whiteleg shrimp aquaculture ponds can be seen in Figure 6.

The genus of the phylum Bacillariophyta found during cultivation consists of *Amphiprora*, *Amphora*, *Chaetocheros*, *Cocconeis*, *Cyclotella*, *Melosira* and *Nitzchia*. Phylum Chlorophyta consists of the genera *Actinastrum*, *Chlamydomonas*, *Chlorella*, *Dictyospaerium* and *Oocystis*. The genera of the phylum Cyanophyta are *Chroococcus*, *Merismopedia* and *Oscillatoria*, while the phylum Dinophyta consists of the genera *Ceratium*, *Peridinium* and *Prorocentrum*. The percentage composition of the phytoplankton genus can be seen in Figure 7. The composition at the beginning of the cultivation was mostly of the *Amphora* genus with a percentage reaching 99.58%, then replaced by Chlorella in the week-2 and from week-9 it was replaced by Oocystis. The highest percentage of *Chlorella* was at week-6, reaching 91.12%, while the highest *Oocystis* was at the end of cultivation, reaching 98.8%.

The abundance of phytoplankton by genus can be seen in Figure 8. The genus with the highest abundance during cultivation was *Oocystis* (Chlorophyta) at 8,094,015 cells/L at the end of cultivation. The genus of the phylum Bacillariophyta which had the highest abundance was the genus *Amphora* at week 0 of 865,231 cells/L. *Chlorella* is a genus of the phylum Chlorophyta which is always found every week during cultivation. The genus Oscillatoria is a genus from the Cyanophyta phylum which has the highest abundance, namely 1,400,814 cells/L in the 12th week, while *Peridinium* is a genus from the Dinophyta phylum which has the highest abundance, namely 13,506 cells/L in the 10th week.

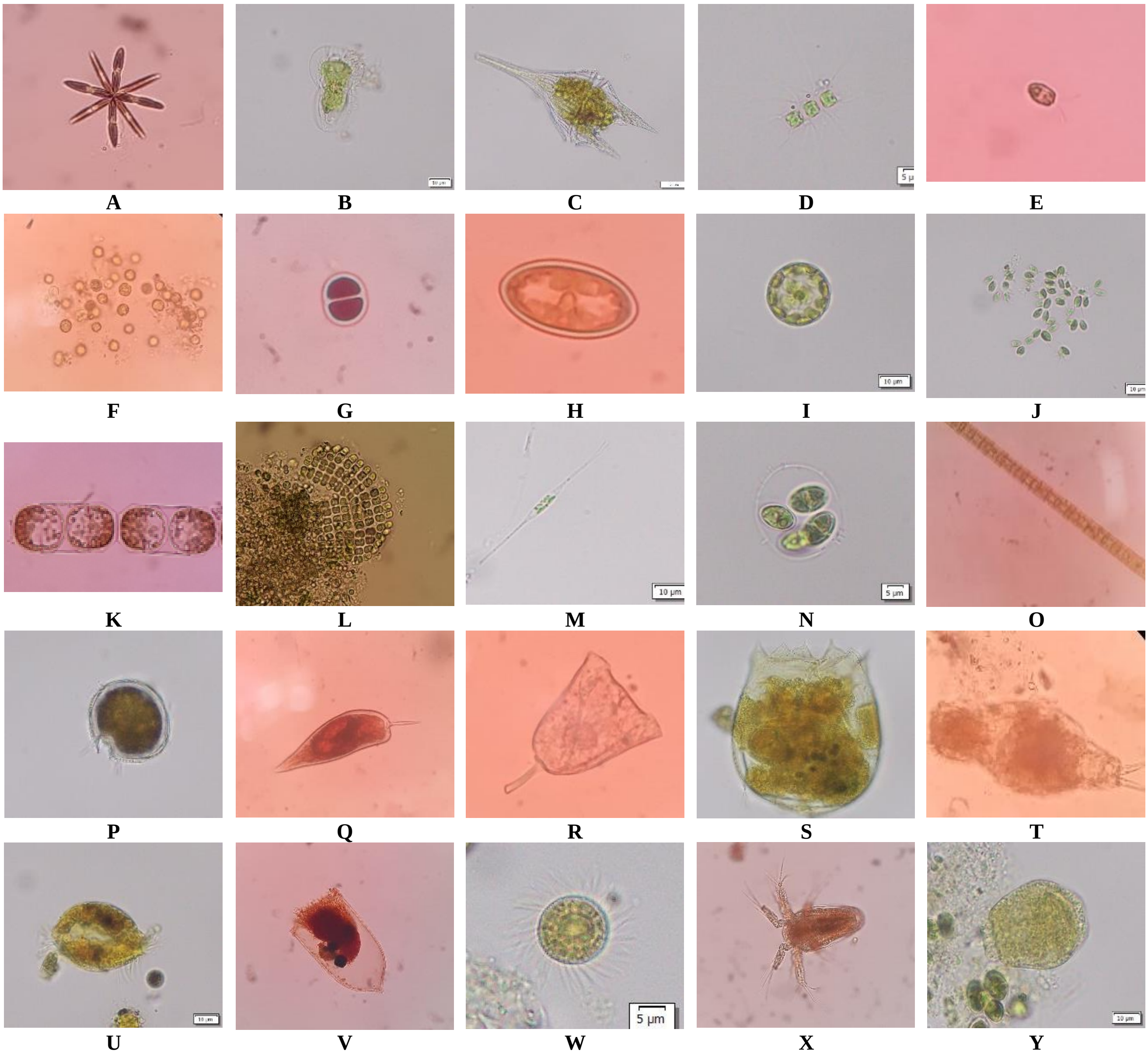

Figure 4. Plankton found in whiteleg shrimp pond, (A-Q) phytoplankton, (R-Y) zooplankton, A. *Actinastrum*, B. *Amphiprora*, C. *Ceratium*, D. *Chaetoceros*, E. *Chlamydomonas*, F. *Chlorella*, G. *Chroococcus*, H. *Cocconeis*, I. *Cyclotella*, J. *Dictyospaerium*, K. *Melosira*, L. *Merismopedia*, M. *Nitzchia*, N. *Oocystis*, O. *Oscillatoria*, P. *Peridinium*, Q. *Prorocentrum*, R. *Acineta*, S. *Brachionus*, T. *Cephalodella*, U. *Euplotes*, V. *Favella*, W. *Halteria*, X. *Nauplius Copepoda*, Y. *Zoothamnium*

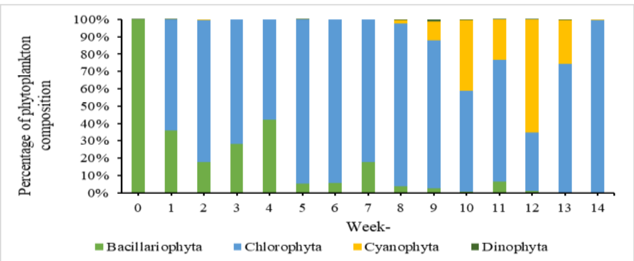

Figure 5. Percentage of phytoplankton composition based on phylum

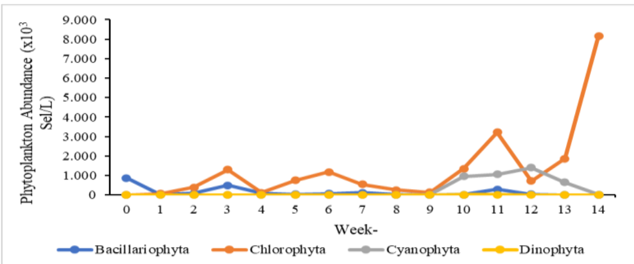

Figure 6. Phytoplankton abundance based on phylum

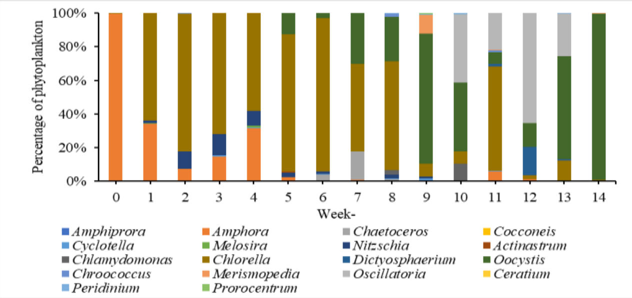

Figure 7. Percentage of phytoplankton composition based on genera

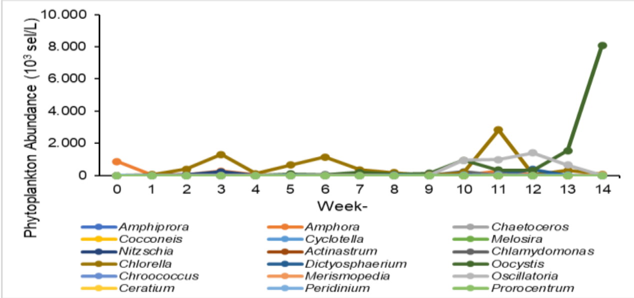

Figure 8. Phytoplankton abundance based on gener

One of the parameters that determine the success of shrimp farming is the abundance of phytoplankton. The abundance of beneficial phytoplankton in whiteleg shrimp ponds is indicated by the presence of Bacillariophyta and Chlorophyta. Chlorophyta is very favorable for shrimp growth, so its presence needs attention (Ni et al. 2018; Palupi et al. 2022). During cultivation, the composition of phytoplankton undergoes changes which may indicate changes in the environmental conditions of the cultivation. The existence of the Chlorophyta phylum indicates that ponds have high levels of organic matter, brightness, pH and nitrate, while temperature, too much oxygen, low salinity and orthophosphate. Phylum Cyanophyta indicates high temperature, ammonia, orthophosphate and salinity conditions, while moderate pH and nitrate and low transparency and TOM values (Mahmudi et al. 2022). One of the phytoplankton genera that is always found every week in this study is *Chlorella*. *Chlorella* is a Chlorophtya group whose presence is quite high in whiteleg shrimp aquaculture ponds. *Chlorella* in cultivation media when consumed by shrimp can increase growth performance by 3% (Sukri et al. 2016; Kamilia et al. 2021; Soeprapto et al. 2023).

Zooplankton

The zooplankton found during the cultivation of whiteleg shrimp consists of 3 phyla with 8 genera. The phyla are Arthropoda, Chiliophora and Rotifera. The composition of zooplankton based on phyla can be seen in Figure 9. The highest percentage of composition reaching 100% includes the Ciliophora phylum at week 0, 1, 3, 5 and 6 and the phylum Rotifera at week-9. Phylum Arthropoda was found towards the final week of cultivation, with the highest percentage in the week-10, reaching 47%.

The highest abundance of zooplankton during cultivation was phylum Ciliophora in the 7th week of 46,725 ind/L. Ciliophora is a fairly numerous phylum and was found almost every week during cultivation, although it was not found in the 9th week. Phylum Arthropoda had the highest abundance in week 10 of 2,555 ind/L, while Rotifera had the highest abundance in week 7 of 8,396 ind/L. The abundance of zooplankton can be seen in Figure 10.

The composition of zooplankton by genus can be seen in Figure 11. The zooplankton from the Arthropoda phylum found in whiteleg shrimp ponds during cultivation consisted of only 1 genus, namely Nauplius copepoda, while the Rotifera phylum contained 2 genera, namely *Brachionus* and *Cephalodella*. The genus in the Ciliophora phylum consists of 5 genera, namely *Acineta*, *Euplotes*, *Favella*, *Halteria* and *Zoothamnium*. The percentage of zooplankton by genus reached 100%, namely *Zoothamnium* at week-0, *Euplotes* at week-5 and *Brachionus* at week-9.

The abundance of zooplankton by genus can be seen in Figure 12. The highest abundance of zooplankton by genus was *Euplotes* in the 7th week of 40,154 ind/L. Euplotes is the zooplankton that is most often found during cultivation. The *Brachious* phylum had the highest abundance in the week-7, which was 8,396 ind/L. *Brachious* is a genus of the Rotifera phylum which is also often found during whiteleg shrimp cultivation.

The zooplankton found in this study are in accordance with the research conducted by Fernandes et al. (2019); Nguyen et al. (2022), who also found zooplankton from the Protozoa (Ciliophora) group such as *Acineta*, *Euplotes* and *Zoothamnium*, the Copepoda Nauplius group and also Rotifera (*Brachionus*). The presence of Protozoa, especially *Euplotes*, indicates the high organic matter in the waters. *Zoothamnium* and *Acineta* are parasites for shrimp so their presence is not beneficial. Rotifers can be used by shrimp as natural food because of their high protein content.

The plankton found in this study changes every week. This indicates a change in pond environmental conditions. According to Setyaningrum et al. (2022); Soeprapto et al. (2023), changes in plankton in ponds can be influenced by various factors including the condition of pond water quality during cultivation and related to water changes during cultivation.

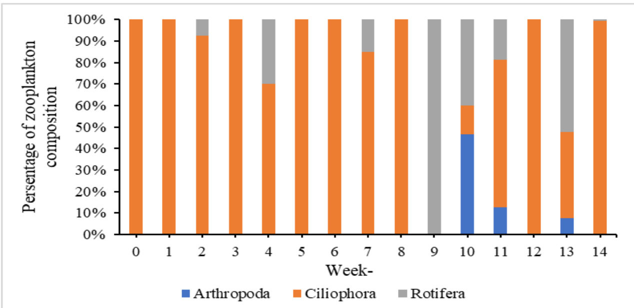

Figure 9. Percentage of zooplankton composition based on Phylum

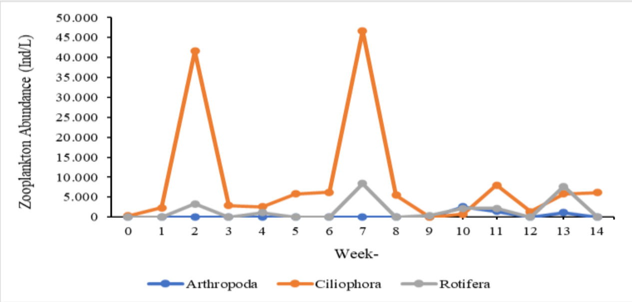

Figure 10. Abundance of Zooplankton based on Phylum

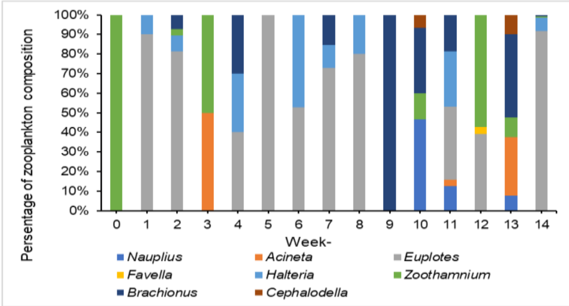

Figure 11. Percentage of zooplankton composition based on genera

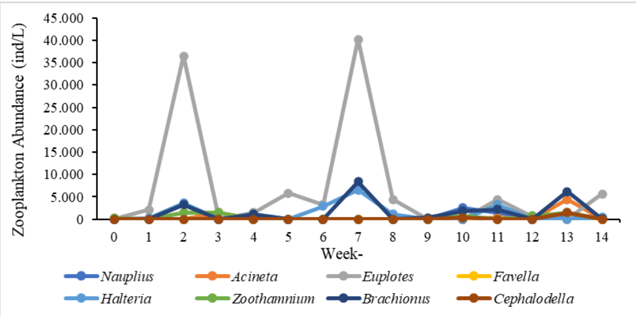

Figure 12. Zooplankton abundance based on genera

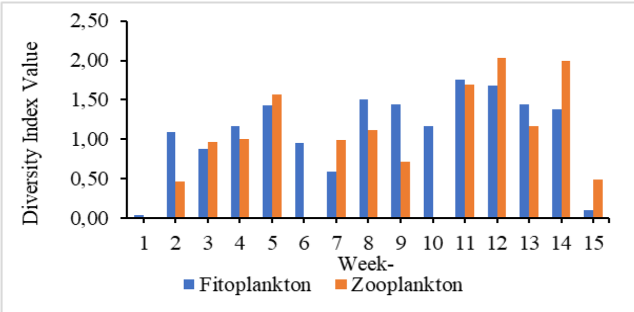

Figure 13. Diversity index of plankton

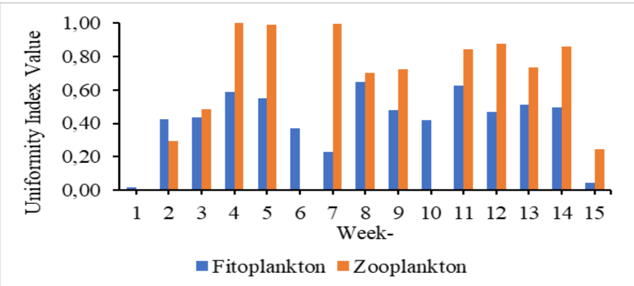

Figure 14. Uniformity index of plankton

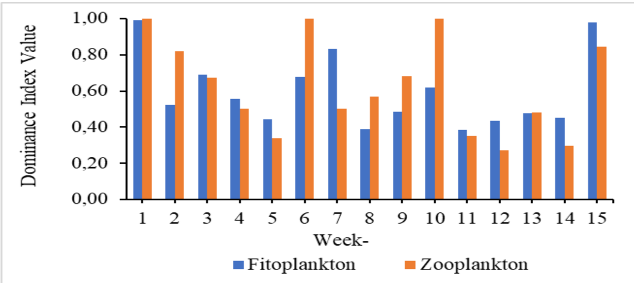

Figure 15. Dominance index of plankton

Diversity, uniformity and dominance index of plankton

The diversity index of phytoplankton ranged from 0.05-1.76, while that of zooplankton ranged from 0-2.03 (Figure 13). This shows that the diversity of phytoplankton and zooplankton in ponds during cultivation is low-medium. The diversity of organisms is low when H < 1, moderate when 1 < H < 3 and high when H > 3 (Odum 1971).

The uniformity index obtained from phytoplankton in whiteleg shrimp ponds during cultivation ranges from 0.02-0.65, while zooplankton ranges from 0 - 1 (Figure 14). The uniformity index results show that the plankton uniformity is low - high. The uniformity value is low if it ranges from 0-0.4, moderate if it is 0.4-0.6 and high if it is 0.6-1 (Odum 1971).

The dominance index of phytoplankton in whiteleg shrimp ponds during cultivation ranged from 0.38 to 0.99, while zooplankton was 0.27 to 1 (Figure 15). This shows that the dominance of an individual is classified as medium-high. Dominance index values close to 1 indicate dominance of certain species (Odum 1971).

The diversity of plankton species found determines the stability and growth of the shrimp. High diversity and uniformity indices indicate ecosystem stability. The high uniformity shows the evenness of the types of organisms that make up an ecosystem. The low value of the uniformity index indicates that there are individuals who dominate because their numbers are higher than other individuals. The existence of dominance indicates competition in an ecosystem, resulting in an imbalance (Vallina et al. 2017; Palupi et al. 2023).

In conclusion, plankton found during whiteleg shrimp cultivation consists of phytoplankton and zooplankton. During cultivation, a change in the type of plankton found indicates a change in the quality of the pond environment. The abundance of plankton increases with increasing cultivation time.

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