BIODIVERSITY AND ABUNDANCE OF PHYTOPLANKTON IN RICE-FISH FARMING SYSTEM

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ABSTRACT

Rice-fish farming system ***that is purposed to maximize land use by adding fish farming to its systems. In the*** **Rice-fish farming system*,*** ***the fish farm serves as a solution to overcome pests so it can provide benefits for the farmers. Fish farm maintenance is considered to be a solution to reduce farmers expenditures in the use of fertilizers. The reason is in the fish-maintaining process, fish will naturally excrete dirt which has a function as organic fertilizer which will increase the fertility of the waters. The purpose of this study was to determine the composition of phytoplankton as well as the physical and chemical quality of the water in several*** **Rice-fish farming system** ***stations in Panembangan Village*** **so** ***that the condition of the ecosystem can be detected whether it is in good or bad condition. The Results showed that the diversity index value ranged from 0.61-1.99. The uniformity index value was obtained in the range of 0.15 – 0.50 and the dominance index value was obtained in the range of 0.20 – 0.72.*** **While, the four stations still have good water quality, the conditions in the Rice-fish farming system area of Panembangan Village are still suitable for the growth of organisms.**

Keywords: Rice-fish, water fertility, phytoplankton, water quality, fertilizer.

التنوع البيولوجي ووفرة الهائمات النباتية في نظام استزراع الأسماك والرز

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المستخلص

نظام زراعة الرز والسمك يهدف إلى تعظيم إستعمال الأراضي عن طريق إضافة تربية الأسماك إلى أنظمتها .في نظام استزراع الرز والسمك ، يعمل حقل الأسماك كحل للتغلب على الآفات حتى يمكن أن توفر فوائد للمزارعين .بأن صيانة حقل الرز يعد حلاً لتقليل نفقات المزارعين في إستعمال الأسمدة .السبب في أن الأسماك تحافظ على هذه الهيمنة .وان الأسماك تطرح المفصلات بشكل طبيعي، التي تعمل كسماد عضوي مما يزيد من خصوبة المياه .هدف هذه الدراسة كان لتحديد تركيبة العوالق النباتية وكذلك الجودة الفيزيائية والكيميائية للمياه في العديد من محطات نظام نداعة الرز والأسماك في قرية بانيمبانغان بحيث يمكن اكتشاف حالة النظام البيئي سواء كانت جيدة أم لا .حالة سيئة .أظهرت النتائج أن قيمة مؤشر التنوع تتراوح بين 0.61-1.99 .تم الحصول على قيمة مؤشر التوحيد في النطاق من 0.15 - 0.50وتم الحصول على قيمة مؤشر الهيمنة في النطاق 0.72 - 0.20 .في حين أن المحطات الأربع لا تزال تتمتع بنوعية جيدة من المياه، وأن الظروف في منطقة نظام زراعة الرز والأسماك في قرية بانيمبانجان لا تزال مناسبة لنمو الكائنات الحية

الكلمات المفتاحية: الآفات، السمك والرز، خصوبة المياه، العوالق النباتية، جودة المياه

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INTRODUCTION

Panembangan Village is one of the villages in Banyumas, with abundant land and water resources and has mountainous contours (17, 24). The majority of people who live in Panembangan Village work as farmers, especially rice and fish cultivators (1). Due to the high demand for rice and fish, as well as the lack of land and time, farmers need an alternative to maintain both incomes. One alternative for obtaining additional income is for farmers to become familiar with a system known as Rice-fish farming system (47). Since 2001, a lot of farmers in Panembangan Village have been using the rice-fish farming technique, which is seen to be highly advantageous and boosts revenue. In this village, the village government has used a 25-hectare parcel of land to maximize the potential for prosperity of the farmers. Rice-fish farming system that maximizes land use with the addition of a fish cultivation system (2, 17). Rice-fish farming system is not a strange thing among the people (21), since the 1950-1960. Rice-fish farming system has been introduced and practiced, but at that time it had not yet developed optimally because the method was still quite traditional. In recent years rice-fish farming system has become a topic that is quite popular among farmers, not without reason, there is an increase in the living needs of farmers and limited rice fields forcing farmers to seek additional income at one time (11). As we know in Indonesia, rice fields, especially paddy can only be harvested 2 times a year, and the profit earned by farmers is quite small (10%) if there is no additional income. The presence of the rice-fish farming method is anticipated to be a way to optimizing land in order to achieve significant and lucrative revenues (9). Rice-fish farming system which utilizes fish farming is a solution for dealing with existing pests, namely natural predators such as planthopper pests. Besides leafhoppers, rats pests will also be a problem, as raising fish requires more water, so the depth of rice fields will increase, which will make it difficult for rats to attack rice plants. Fish rearing is also considered to be a solution to reduce farmers expenditure on fertilizer use (13). Because fish excrete excrement in the process of rearing them, which serves as organic fertilizer for increasing water quality (46). The Mina Padi system further explained how disease factors can be minimized in fish. Several bacteria cause diseases in fish farming such as *Aeromonas hydrophila* and *Pseudomonas aeruginosa* (20). *Saprolegniasis* (6, 7, 33). Water fertility is an illustration of the high and low productivity of waters (34, 8). The primary productivity of waters is strongly dependent on the presence of organisms capable of photosynthesis, such as phytoplankton (12). Phytoplankton is the main chain in an aquatic ecosystem (40, 19). As the main producer, the presence of phytoplankton will affect a higher tropic level (25). The levels in the waters start with phytoplankton, then are followed by zooplankton and move on to small and large fish. The water fertility and conditions that support phytoplankton growth will boost their ability to grow (15, 5). A high density of phytoplankton can be a bioindicator of a waters (27). Water quality certainly has a big impact on yields (14, 35). Similarly, pollution of the waterways will reduce the fertility of the waters. It is crucial to assess the water's quality and fertility. The fertility of waters in general can be measured by knowing the diversity or composition of the phytoplankton in the water, The advantage of this method is that it indirectly determines the balance or condition of an ecosystem. This study's objective was to identify the phytoplankton species present and the water's physical and chemical characteristics at several rice-fish farming system stations in Panembangan Village, so that the condition of the ecosystem can be determined whether it is in good or bad condition.

MATERIAIS AND METHODS

This study was conducted in June 2022, with 4 different rice-fish farming system locations in Panembangan Village, Banyumas (Station 1, 2, 3 and 4)) (Figure 1). The sampling distance between research stations varies according to the location of each existing rice-fish farming system group. The closest distance to the research station is between stations 1 and 2 which are within a radius of 100 meters. Then the farthest distance is at station 3 with a radius of more than 200 meters measured from station 1 and station 2. Meanwhile, station 4 is the farthest station at the end of the village, with a radius of 1 kilometer from station 1, 2 and 3. In all four locations of different rice-fish farming system groups. Water samples (phytoplankton) were collected three times a week and chemical waters were measured physically three times a week. Water sampling (phytoplankton) uses tools in the form of a bucket of 10 liter and also a plankton net (4). The water sample obtained was then observed in the laboratory with a census method of 30 fields and 3 times each sample. The identifying information was then used to calculate abundance (N), relative abundance (KR), diversity index (H'), uniformity index (E), and dominance index (C) using the formula below (37):

$$\mathbf{N} = \frac{Oi}{Op} x \frac{Vr}{Vo} x \frac{1}{Vs} x \frac{n}{p}$$

Where:

N: Total number of plankton (ind/L)

Oi: Cover glass area (324 mm^2)

Op: One field of view's area (1.11279 mm^2)

Vr: Sample water volume in the collecting bottle (75 ml)

Vo: One drop of sample water volume (0.05 ml)

Vs: Water volume filtered by a plankton net (100L)

n: The total number of plankton in the area of vision

p: Number of visual fields (30)

$$\mathbf{KR} = \frac{a}{a+b+c}$$

Where:

a: Total number of members of a certain species discovered

a, b, c : Total number of species found

$$\mathbf{H'} = -\sum_{i=1}^{s} 0\, Pi\, ln\, Pi$$

Where:

H': Shannon-Wiener diversity index

Pi: The number of individuals belonging to each species (Pi = $\frac{ni}{N}$)

ni: The number of individuals in the i-th species

N: The total number of individuals in a community

Table 1. diversity index value

Diversity Value	Category
H' < 1	Low diversity
1 < H' < 3	Moderate diversity
H' > 3	High diversity

$$\mathbf{E} = \frac{H'}{lS}$$

Where:

E: Uniformity index

H': Shannon-Wiener diversity index

: The number of genus or species types

Table 2. Uniformity index value

Uniformity Value	Category
0.00 < E < 0.50	Low uniformity
0.50 < E < 0.75	Moderate uniformity
0.75 < E < 1.00	High uniformity

$$\mathbf{C} = \Sigma \left(\frac{ni}{n}\right)^2$$

Where:

C: Dominance Index

ni: The number of individuals in the i-th species

n: The total number of individuals

Table 3. Dominance index value

Dominance Value	Category
0.00 < C < 0.50	Low dominance
0.50 < C < 0.75	Moderate dominance
0.75 < C < 1.00	High dominance

Water quality measurements were performed immediately at the research site, eliminating the requirement for laboratory analysis, utilizing a water quality checker that can read numerous parameters directly, including temperature, salinity, DO, pH, and TDS.

Table 4. Water quality measurement parameters

No	Parameter	Unit
1.	Temperature	°C
2.	Salinity	Ppt
3.	Ph	-
4.	DO	mg/L
5.	TDS	mg/L

The map below shows the location of Penambengan Village, Kec. Cilongok, Kab. Banyumas, with 4 different stations representing each of the rice-fish farming system groups in the village

RESULTS AND DISCUSSION

Phytoplankton composition

The results of observations of phytoplankton taken at 4 different locations of rice-fish farming system in Panembangan village, obtained a composition consisting of 3 classes and 29 genera, which are presented in Table 5:

Table 5. Plankton identification results

Class	Genera
Bacillariophyceae	*Navicula, Nitzschia, Surirella, Synedra, Cymbella, Gyrosigma, Pinnularia, Eunotia*
Chlorophyceae	*Closterium, Scenedesmus, Asterococcus, Chlorella, Coelastrum*
Cyanophyceae	*Melosira, Oscillatoria, Spirulina*

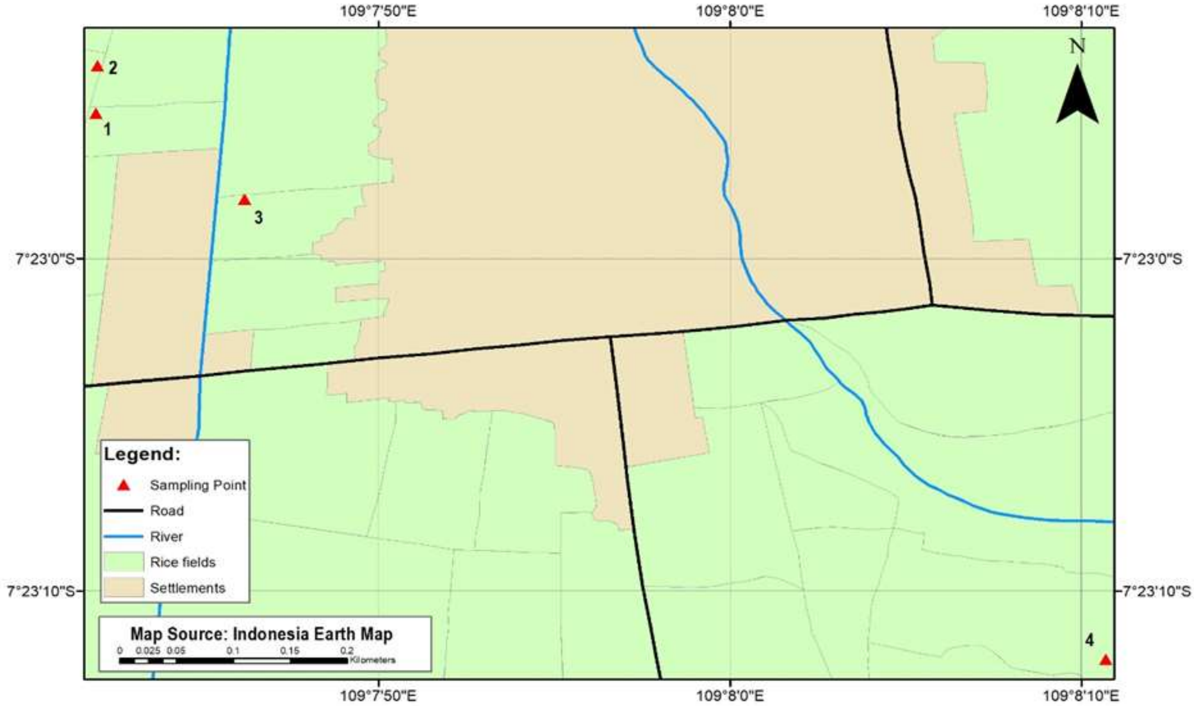

Figure 1. Map of research locations

The composition of the phytoplankton found in the observations generally came from 3 classes, namely *Bacillariophyceae*, *Chlorophyceae*, and *Cyanophyceae* with the highest average abundance found at station 3, with a total of 4416 cells L^{-1} followed by station 1 of 3979 cells L^{-1}, station 2 is 3057 cells L^{-1}, and the lowest was at station 4 with a value of 2620 cells L^{-1}. In general, all data collecting stations had the highest concentration of phytoplankton from the Bacillariophyceae class. Station 3 has the largest abundance of the Bacillariophyceae class, with a total of 12665 cells L^{-1}, followed by station 1 with a total of 11501 cells L^{-1}, then station 2 with a total of 9172 cells L^{-1} and the lowest was at station 4 with several *Bacillariophyceae* only 6114 cells L^{-1}(Figure 2)

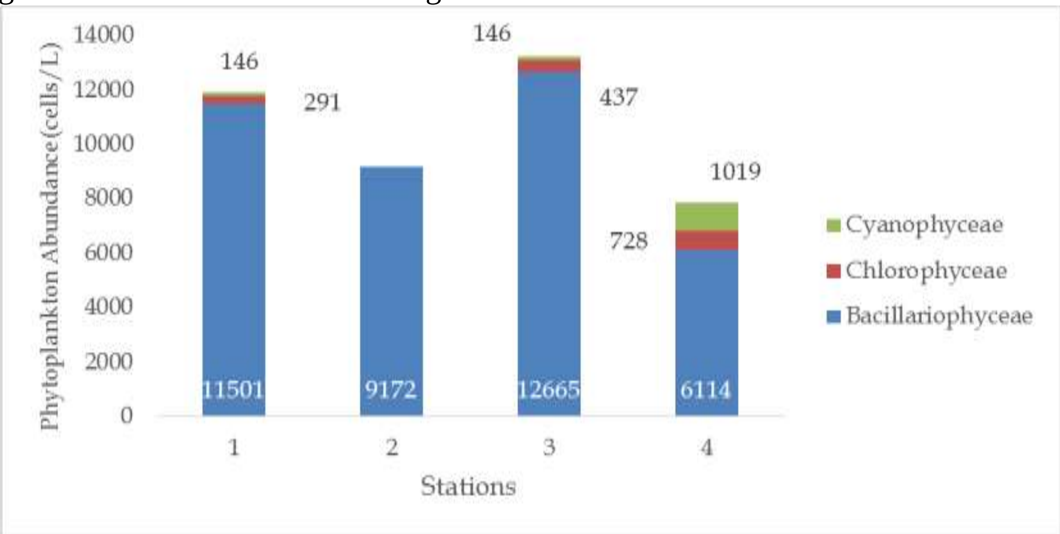

Figure 2. Phytoplankton abundance at four stations

Based on relative abundance, the species that dominated the 4 rice-fish farming system data collection stations came from the class *Bacillariophyceae* namely *Navicula* sp. followed by *Nitzschia* sp. The results showed that the relative abundance of *Navicula* sp ranged from 37% - 84% with the lowest value at station 4 and the highest value at station 2. As for the value of *Nitzschia* sp, values obtained ranged from 10% - 17% with the lowest value at station 2 and 3, and the highest at station 4, while the data is shown as follows (Figure 3):

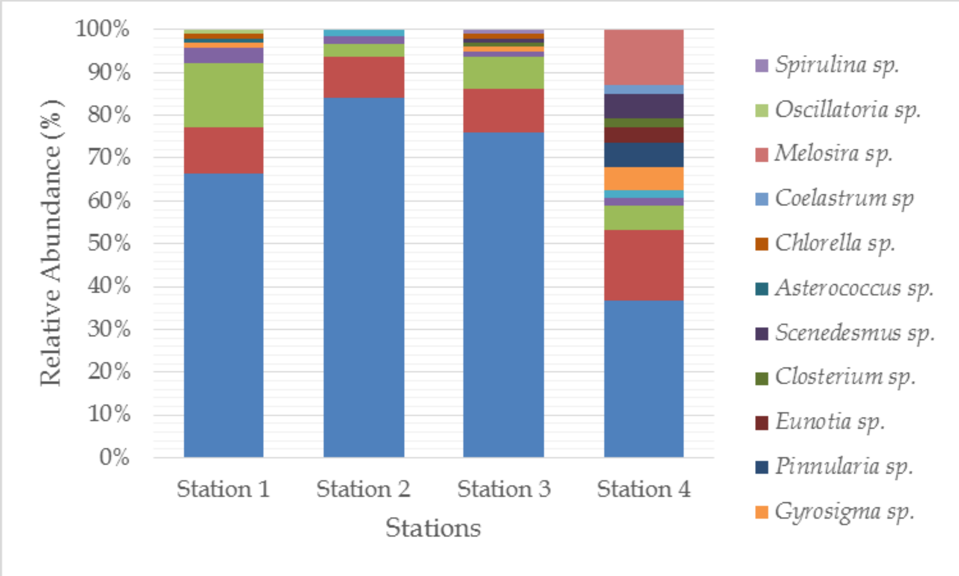

Figure 3. Relative abundance

Phytoplankton diversity, uniformity, and dominance index : Based on the phytoplankton composition, the index of diversity, uniformity, and dominance can be determined as an illustration of ecosystem stability based on the calculated results. Values of the index can be seen in **Table 6** which has been presented.

Table 6. Diversity, uniformity, and dominance index values

Station	H'	Category	E	Category	C	Category
1	1.13	Moderate	0.55	Moderate	0.47	Low
2	0.61	Low	0.38	Low	0.72	Moderate
3	0.93	Low	0.42	Low	0.59	Moderate
4	1.99	Moderate	0.80	High	0.20	Low

The diversity index obtained from the four observation stations ranging from 0.61 to 1.99. Stations 1 and 4 had values in the moderate category of 1.13 and 1.99, respectively. This is in contrast to station 2, which has a score of 0.61, and station 3, which has a value of 0.93 and is classified as low. The phytoplankton diversity index values at each station of the rice-fish farming system differed considerably, showing that no meaningful difference exists in this region. Balanced diversity implies that the distribution happens quite evenly at each station and that there are no factors that repress nature, implying that natural conditions are still relatively well preserved.This condition is confirmed by the results of calculating the uniformity values at each station, which yield values ranging from 0.38 to 0.80, with station 2 having the lowest value of 0.38 and station 4 having the highest value of 0.80, both of which are in the quite high category. A high uniformity rating suggests the existence of a dominant species with a generally even makeup. Station 2, which comes under the category of medium dominance, received the highest value, a score of 0.72. By having values for the diversity, uniformity, and dominance indices that are not significantly different, this value further demonstrates that the ecology in the waters around Penambengan Village's rice-fish farming system is still usually relatively stable.

Water quality

The physical and chemical quality of the waters conducted in Penambengan Village are presented in the Table 7.

Table 7. Water quality measurments stations

No	Parameters	Stations 1	2	3	4
1	Temperature (°C)	27	28	28	28
2	pH	7.2	7.1	7.2	7.0
3	Salinity (ppt)	0.04	0.04	0.04	0.03
4	TDS (mg/L)	50.8	53.8	50.6	48.9
5	DO (mg/L)	7.7	3.4	6.6	7.0

Temperature measurements at the four separate rice-fish farming system sites yielded very consistent results, ranging from 27 to 28 °C, which is considered warm water. This is consistent with the explanation provided by (41) research. The ideal temperature for nila fish development is 27 °C. Likewise, with the values for measuring the degree of acidity (pH) obtained at each station, the values obtained were not much different, which ranged from 7.0 – 7.2, included in neutral category. Regarding the salinity data, it was discovered that there were not many differences across the four observation sites, with values ranging from 0.03 to 0.04 ppt, which falls into the category of low salt content and is adequate for fresh waters. The Total Dissolved Solids (TDS) value obtained demonstrates the same thing. While the dissolved material concentration ranged from 48.9 to 53.8 mg/L, which is exceptionally high for water. There are some differences in the concentrations of dissolved oxygen among the stations tested, with values fluctuating between 3.4 to 7.7 mg/L, with the minimum value at station 2 and the highest value at station 1.

Phytoplankton composition

According to the field data, there were three groups of phytoplankton: Bacillariophyceae, Chlorophyceae, and Cyanophyceae. These three groupings are frequently numerous due to their ability to adjust and survive in fresh water, especially the rice-fish farming method. All three classes are present at all observation locations, however station 3 has the highest abundance while station 4 has the lowest. The high abundance of phytoplankton is thought to be a factor in water input. The presence of abundant channels or water sources facilitates the process of transferring phytoplankton which is carried by currents when there is a change of water (26). This is proven by the data obtained, where the locations of stations 3, 2, and 1 (close to waterways) have a greater abundance than station 4 which has relatively far and quite small waterways. Phytoplankton, which cannot move freely, is certainly greatly helped by the presence of flowing water. Apart from the incoming water, of course, the current speed is also very important in the distribution of this phytoplankton, especially in freshwater (16). According to (17), nutrient content in water is tightly connected to phytoplankton abundance, with increased nutrients in water resulting in greater phytoplankton abundance and chlorophyll-a concentration. The quantity of chlorophyll-a in water may be used to evaluate the level of fertility of the water by providing an indirect measure of the number of phytoplankton. The results showed that the phytoplankton species from the three classes found, *Navicula* sp were the species that dominated the waters at the rice-fish farming system location in Penambengan Village. *Navicula* sp. It is known that it can be found in all waters, from freshwater, and estuaries to seawater (44). Even though *Navicula* is not the main producer in the waters, their presence can be used as a bio-indicator of water fertility. The abundance of *Navicula* sp. This shows that these waters have high water quality and nutrients to meet their growth needs. Pham (39) demonstration said that *Navicula* sp. is a bioindicator of waters that have experienced euthanasia because of its ability to absorb nutrients in the waters. It was further explained by Segura-Garcial (45) that *Navicula* species also have abundant characteristics in locations that are influenced by river flow and rainwater input. This is comparable to the characteristics of the water in the rice-fish farming system in Panembangan Village, which is located at the foot of Mount Slamet and has a lot of water and rain. The resulting uniformity values, which are not substantially different, support these conclusions. A high uniformity grade indicates that no single species dominates and that the species mix is generally balanced (30). This is further supported by dominance values that are not too different, indicating that the species adapted well and fairly evenly, however, they are still dominated by the *Bacillariophyceae* class, namely by the species *Navicula* sp (44).

Environmental factors

Self-survival factor of *Navicula* sp. is quite good and also geographical conditions that support it, reinforced by water conditions that are quite suitable. The results of measurements of water temperature obtained are optimal where phytoplankton can live in a temperature range of 20 – 30 °C (38). The relatively stable conditions obtained at this location are thought to be due to optimal irradiation that occurred during data collection, namely in June (23). his result is also following the measurement of water quality parameters in the form of acidity (pH). The pH values obtained by the four stations ranged from 7.0 - 7.2 with the highest pH at stations 1 and 3. These pH values are still at the optimal limit for plankton growth (28). pH conditions that are too high can be a limiting factor for phytoplankton in carrying out metabolism and development (29). Aside from pH, salinity is a crucial element in plankton viability. Because salinity is closely connected to ocean oxygen levels, it is a limiting factor (31). The higher the level of salinity, the lower the amount of oxygen in the water (22). In general, the ideal salinity for phytoplankton in fresh waters varies between 0 and 5 ppt (43). The salinity levels found in this investigation ranged from 0.03 to 0.04, which is fairly excellent for fresh water. Dissolved oxygen is another component that affects phytoplankton life since it has a biological function of growth in water. Many variables, such as temperature and salinity (31), impact high or low oxygen levels in water. The oxygen levels obtained varied from 3.4 to 7.7 mg/L, according to the data collected. In general, biota, including phytoplankton, may thrive when the lowest oxygen level is more than 2 mg/L (32), implying that the value attained in this research habitat is sufficient to enable phytoplankton life. The value of total dissolved solids (TDS) is the last measurement of the physical quality of the water. TDS is a limiting element in phytoplankton viability (42). Some plankton that is autotrophic have the ability to photosynthesize which is strongly influenced by the irradiation that enters the waters. The high TDS will interfere with plankton absorption of light (3). The TDS value in Penambengan Village varied from 48.9 to 53.8 mg/L based on the measurements made, which is fairly high. The high value is strongly tied to the state of the research area, which is in the shape of rice fields with a mud substrate. When sustained by a sufficiently strong water supply, mud substrate tends to yield high TDS levels (36).

CONCLUSION

According to the phytoplankton composition data, the degree of phytoplankton diversity in the Panembangan Village rice-fish farming system region is in the low to moderate category, with a value ranging from 0.61-1.99 with the species Navicula sp. identified at every station. This shows that the types of phytoplankton in the area are evenly distributed. The uniformity index value obtained varied from 0.15 to 0.50, indicating that it is relatively poor. A relatively low uniformity rating suggests that no particular species dominates and that the mix is reasonably even. While the domination index value obtained varied from 0.20 to 0.72, indicating that the amount of dominance in the region is low to moderate. The four stations' water quality remains within the quality level, proving that the region's rice-fish farming system waterways are still ideal for organism existence. The TDS parameter, on the other hand, has a rather high value, ranging from 48.9 to 53.8 mg/L. This might be due to the state of the research station substrate, which is a paddy field with a basic substrate in the form of mud, causing the TDS value to rise.

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REFERENCES

1. Anbari, I., R. Fitriadi, M. Nurhafid, and M. Palupi. 2022. Isolation and characterization of proteolytic bacteria from the waters of the rice

mina culture system. Jurnal Lemuru, 4(2), 46-56
2. Ahmed, N., and S.T Garnett. 2011. Integrated rice-fish farming in Bangladesh: Meeting the challenges of food security. Food Security, 3(1), 81–92. https://doi.org/10.1007/s12571-011-0113-8
3. Ajmer, L., B.L Hurda, A. Vijayvergiya, and R. Vyas. 2019. Assessment of Primary Productivity and Plankton Population in Anasagar. 9, 1067–1071
4. Anggreni, A.A.M.D., I.W. Arnata, and I.B.W. Gunam. 2021. Microalgae Isolation found in Kedonganan beach, Badung Bali, Indonesia. IOP Conference Series: Earth and Environmental Science, 913(1). https://doi.org/10.1088/1755-1315/913/1/012067
5. Asch, R.G., C.A. Stock, and J.L. Sarmiento. 2019. Climate change impacts on mismatches between phytoplankton blooms and fish spawning phenology. Global Change Biology, 25(8), 2544–2559. https://doi.org/10.1111/gcb.14650
6. Alwash, S.W., J.K. Al-Faragi, and T.M. Al-Saadi. 2022. Effeciency of copper nanoparticles coated mint as anti-fungal against *saprolegniasis* disease in common carp. Iraqi Journal Of Agricultural Sciences, 53(5), 1129-1137. https://doi.org/10.36103/ijas.v53i5.1626
7. Al-Hassani, S.T., and S.A. Mustafa. 2022. Efficiency of synbiotic as feed additives on growth performance, survival rate and health status in common carp challenged with Saprolegnia Spp. Iraqi Journal of Agricultural Sciences, 53(2), 397-405. https://doi.org/10.36103/ijas.v53i2.1548
8. Azmi, K.A., S. Arsad, and L.A. Sari. 2020. The effect of commercial nutrients to increase the population of Skeletonema costatum on laboratory and mass scales. In IOP Conference Series: Earth and Environmental Science (Vol. 441, No. 1, p. 012039). IOP Publishing
9. Bandla, G., P. Bohra, P. Blair, H. Haridas, and S. Krishnan. 2019. An overview of integrated farming systems of coastal india. Icar- Central Island Agricultural Research Institute.
10. Bashir, M.A., J. Liu, Y. Geng, H. Wang, J. Pan, D. Zhang, A. Rehim, M. Aon and H. Liu. 2020. Co-culture of rice and aquatic animals: An integrated system to achieve production and environmental sustainability. Journal of Cleaner Production, 249. https://doi.org/10.1016/j.jclepro.2019.119310
11. Bosma, R.H., D.K. Nhan, H.M.J. Udo, and U. Kaymak. 2012. Factors affecting farmers' adoption of integrated rice-fish farming systems in the Mekong delta, Vietnam. Reviews in Aquaculture, 4(3), 178–190. https://doi.org/10.1111/j.1753-5131.2012.01069.x
12. Chishty, N., and N. L Choudhary. 2022. Seasonal dynamic in primary productivity and phytoplankton diversity in berach river system of udaipur district, rajasthan. Asian Journal of Biological and Life Sciences, 11(1), 82–92. https://doi.org/10.5530/ajbls.2022.11.12
13. Da, C.T., P.A. Tu, J. Livsey, V. Tang, H. Berg, and S. Manzoni. 2020. Improving productivity in integrated fish-vegetable farming systems with recycled fish pond sediments. Agronomy, 10(7). https://doi.org/10.3390/agronomy10071025
14. Durodola, O.S., and K.A. Mourad. 2020. Modelling maize yield and water requirements under different climate change scenarios. Climate, 8(11), 1–26. https://doi.org/10.3390/cli8110127
15. Damayanti, K.Y., A.S. Mubarak, and L.A. Sari. 2020. The effect of giving fermented rice bran suspension on fecundity and production of Moina macrocopa offspring per parent. In IOP Conference Series: Earth and Environmental Science (Vol. 441, No. 1, p. 012156). IOP Publishing
16. Dwirastina, M., and D. Atminarso. 2021. Evaluation of the conditions of mamberamo river water with biomass and phytoplankton community approach. Jurnal Ilmiah Perikanan dan Kelautan, 13(1), 38-47
17. Diana, A., N. Zahro, L.A. Sari, S. Arsad, K.T. Pursetyo, and Y. Cahyoko. 2021. Monitoring of phytoplankton abundance and chlorophyll-a content in the estuary of Banjar Kemuning River, Sidoarjo Regency, East Java. Journal of Ecological Engineering, 22(1).
18. Fitriadi, R., M.,Palupi, R. F.,Azhari, R. A., Candra, and P. Sukardi, 2023. Distribution and diversity of Gastropods in the rice-fish farming system. Biodiversitas Journal of Biological Diversity, 24(4).

19. Golubkov, S.M., N.V. Shadrin, M.S. Golubkov, E.V. Balushkina, and L.F. Litvinchuk. 2018. Food chains and their dynamics in ecosystems of shallow lakes with different water salinities. Russian Journal of Ecology, 49(5), 442–448. https://doi.org/10.1134/S1067413618050053

20. Garabawi, A.J., J.K. Al-Faragi, and K.Y Zakair. 2022. Detection of the most important pathogenic bacteria affect external organs of cyprinus carpio in wasit province. Iraqi Journal Of Agricultural Sciences, 53(5), 1115-1122. https://doi.org/10.36103/ijas.v53i5.1624

21. Halwart, M., and M.V. Gupta. 2004. Culture of fish in rice fields Edited by Matthias Halwart

22. Hintz, W.D., and R.A. Relyea. 2019. A review of the species, community, and ecosystem impacts of road salt salinisation in fresh waters. Freshwater Biology, 64(6), 1081–1097. https://doi.org/10.1111/fwb.13286

23. Jatiandana, A.P., and S. Nurdjaman. 2020. Identification of thermal front in Indonesian waters during 2007 - 2017. IOP Conference Series: Earth and Environmental Science, 618(1). https://doi.org/10.1088/1755-1315/618/1/012039

24. KKP, 2022. Pengembangan Panembangan Smart Fisheries Villages. Balai Besar Riset Sosial Ekonomi Kelautan Dan Perikanan Badan Riset Dan Sdm Kelautan Dan Perikanan.

25. Lewis, A.S.L., B.S. Kim, H.L. Edwards, H.L. Wander, C.M. Garfield, H.E. Murphy, N.D. Poulin, S.D. Princiotta, K.C. Rose, A.E. Taylor, K.C. Weathers, C.R. Wigdahl-Perry, K. Yokota, D.C. Richardson, and D.A. Bruesewitz. 2020. Prevalence of phytoplankton limitation by both nitrogen and phosphorus related to nutrient stoichiometry, land use, and primary producer biomass across the northeastern United States. Inland Waters, 10(1), 42–50. https://doi.org/10.1080/20442041.2019.1664233

26. Li, Q., G. Wang, Z. Tan, and H. Wang. 2020. Succession of phytoplankton in a shallow lake under the alternating influence of runoff and reverse water transfer. Hydrology Research, 51(5), 1077–1090. https://doi.org/10.2166/nh.2020.163

27. Li, Y., M. Geng, J. Yu, Y. Du, M. Xu, W. Zhang, J. Wang, H. Su, R. Wang, and F. Chen. 2022. Eutrophication decrease compositional dissimilarity in freshwater plankton communities. Science of the Total Environment, 821(January), 153434. https://doi.org/10.1016/j.scitotenv.2022.153434

28. Madusari, B.D., J.W. Hidayat, D.E. Wibowo, and C. Muhammad. 2017. The differences in phytoplankton community structure of pond waters between Pemalang and Brebes, Central Java, Indonesia. Advanced Science Letters, 23(7), 6402–6405. https://doi.org/10.1166/asl.2017.9636

29. Mawarni, A., F.N.N. Azizah, H.W. Sartika, S. Hadisusanto, D.M. Putri, and A. Reza. 2020. Short communication: Community of phytoplankton in peatland canal, riau, and wet dune slacks of parangtritis, yogyakarta, indonesia. Biodiversitas, 21(5), 1874–1879. https://doi.org/10.13057/biodiv/d210513

30. Melati, V.H., L.A. Sari, Y. Cahyoko, S. Arsad, K.T. Pursetyo, N.N. Dewi, and M.H. Idris. 2021. Gastropod community structure as environmental change signals for tropical status in sedati waters, indonesia. Ecological Engineering and Environmental Technology, 22(3), 82–90. https://doi.org/10.12912/27197050/135508

31. Mo, Y., F. Peng, X. Gao, P. Xiao, R. Logares, E. Jeppesen, K. Ren, Y. Xue, and J. Yang. 2021. Low shifts in salinity determined assembly processes and network stability of microeukaryotic plankton communities in a subtropical urban reservoir. Microbiome, 9(1), 1–17. https://doi.org/10.1186/s40168-021-01079-w

32. Mohan, M., G.S. Prasad, R.K. Dash, and K. Vijay. 2022. Fabricated aerators influence on oxygen dissolution in pond water during day and nighttime. The Pharma Innovation, 11(10), 2351–2358

33. Mustafa, S.A., A.J. Al-Rudainy, and J.K. Al-Faragi. 2019. Assessment of hydrogen peroxide on histopathology and survival rate in common carp, Cyprinus carpio l. infected with *saprolegniasis*. The Iraqi Journal of Agricultural Science, 50(2), 697-704. https://doi.org/10.36103/ijas.v2i50.669

34. Musa, M., S. Arsad, L.A. Sari, E.D. Lusiana, R.D. Kasitowati, E.N. Yulinda, ... and D. Cahyani. 2021. Does Tofu Wastewater Conversions Nutrient Increase the Content of the Chlorella pyrenoidosa?. Journal of Ecological Engineering, 22(2), 70-76

35. Mubarak, A.S., K.T. Pursetyo, and A. Monica. 2020. Quality and quantity of ephipia moina macrocopa resulting from mating using tilapia fish feces suspension feed. The Iraqi Journal of Agricultural Science, 51, 157-167. https://doi.org/10.36103/ijas.v51iSpecial.893

36. Nurdin, J., D. Irawan, H. Syandri, Nofrita, and Rizaldi. 2020. Phytoplankton and the correlation to primary productivity, chlorophyll-a, and nutrients in lake maninjau, west sumatra, indonesia. AACL Bioflux, 13(3), 1689–1702

37. Nurfadillah, N., D. Desrita, I. Dewiyanti, R.S. Rahayu, S. Maulidawati, S. Sari, S. Surikawati, and I. Karina. 2022. Community structure of plankton in Aneuk Laot Lake Sabang Pulau Weh. E3S Web of Conferences, 339, 03008. https://doi.org/10.1051/e3sconf/202233903008

38. Padfield, D., G. Yvon-Durocher, A. Buckling, S. Jennings, and G. Yvon-Durocher. 2016. Rapid evolution of metabolic traits explains thermal adaptation in phytoplankton. Ecology Letters, 19(2), 133–142. https://doi.org/10.1111/ele.12545

39. Pham, T.L. 2020. Using benthic diatoms as a bioindicator to assess Rural-Urban River conditions in tropical area: A case study in the Sai Gon River, Vietnam. Pollution, 6(2), 387–398. https://doi.org/10.22059/POLL.2020.292996.716

40. Palupi, M., R. Fitriadi, R. Wijaya, P. Raharjo, and R. Nurwahyuni. 2022. Diversity of phytoplankton in the whiteleg (Litopenaeus vannamei) shrimp ponds in the south coastal area of Pangandaran, Indonesia: Diversity of Phytoplankton in the Whiteleg (litopenaeus vannamei) Shrimp Pond. Biodiversitas Journal of Biological Diversity, 23(1).

41. Putri, A.O., O.Y.T. Pamula, Y. Fakhriah, A. Manan, L.A. Sari, and N.N. Dewi. 2019. The comparison of water spinach (Ipomoea aquatica) density using aquaponic system to decrease the concentration of ammonia (NH3), nitrite (NO2), nitrate (NO3) and its effect on feed conversion ratio and feed efficiency to increase the survival rate and specific growth rate of African catfish (Clarias sp.) in intensive aquaculture. Journal of Aquaculture and Fish Health, 8(2), 113-122

42. Rizal, A., I.M. Apriliani, and L.P. Dewanti. 2022. Water quality index based on interrelation between plankton and benthos in Cimanuk River , Majalengka District , West Java , Indonesia. World Scientific News, 168, 81–98

43. Sahidin, A., I. Nurruhwati, I. Riyantini, and M. Triandi. 2019. Structure of Plankton Communities in Cijulang River Pangandaran District , West Java Province , Indonesia. 23(January), 128–141

44. Saputro, T.B, K.I. Purwani, D. Ermavitalini, and A.F. Saifulloh. 2019. Isolation of high lipid content microalgae from wonorejo river, Surabaya, Indonesia and its identification using rbcL marker gene. Biodiversitas, 20(5), 1380–1388. https://doi.org/10.13057/biodiv/d200530

45. Segura-García, V., E.A. Cantoral-Uriza, I. Israde, and N. Maidana, 2012. Epilithic diatoms (*Bacillariophyceae)* as indicators of water quality in the Upper Lerma River, Mexico. Hidrobiologica, 22(1), 16–27

46. ShunLong, M., H. GengDong, L. DanDan, Q. LiPing, S. Chao, F. LiMin, Z. Yao, W. Wei, C. JiaZhang, and B. XuWen. 2018. Research progress of rice-fish integrated farming. Agricultural Biotechnology, 7(4), 129–135

47. Su, M., M. Wang, Y. Sun, and Y. Wang. 2022. Tourist Perspectives on Agricultural Heritage Interpretation—A Case Study of the Qingtian Rice-Fish System. Sustainability (Switzerland), 14(16). https://doi.org/10.3390/su141610206