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The Correlation Between Macrobenthic Mollusk Community Structure, Water Quality, and Sediment for Evaluating the Environmental Status of the Aquaculture Area in Lake Rawapening

Isman Nasik[1*], Sapto Purnomo Putro[2], Rully Rahadian[1], and Muhammad Choirul[1]

[1]Depatement of Biology, Faculty of Science and Mathematics, Diponegoro University, Semarang, Indonesia; e-mail: Mail.ismannsik@gmail.com
[2]Center of Marine Ecology and Biomonitoring for Sustainable Aquaculture, Diponegoro University, Central Java, Indonesia

ABSTRAK

Karena lonjakan permintaan pangan secara global, budidaya perikanan di Indonesia berkembang dengan sangat cepat. Kegiatan budidaya ikan dengan menggunakan keramba jaring apung yang mengabaikan pencemaran lingkungan menjadi permasalahan yang signifikan di Danau Rawapening. Moluska makrobentos berfungsi sebagai bioindikator yang berharga untuk menilai gangguan pada ekosistem perairan karena memiliki perilaku menetap, pergerakan yang lambat, serta sensitivitas tinggi terhadap fluktuasi kualitas air. Penelitian ini bertujuan menilai struktur komunitas moluska makrobentos, kualitas lingkungan, dan status ekologis di area budidaya Danau Rawapening. Sampel sedimen diambil dari lokasi polikultur, monokultur, dan area referensi. Ditemukan 9 spesies dari 2 kelas dan 7 famili di ketiga lokasi, dengan indeks keanekaragaman (H') yang rendah, mencerminkan stabilitas komunitas yang terbatas. Keanekaragaman lebih tinggi di lokasi polikultur dibandingkan monokultur. Analisis abiotik menunjukkan parameter lingkungan (suhu, pH, C-organik, N-total, fosfat) parameter masih sesuai dengan standar kualitas, meskipun kadar oksigen terlarut (DO) rendah. Substrat didominasi lanau berlempung. faktor abiotik yang paling berkorelasi dengan kelimpahan moluska adalah Suhu (r = 0,612; BIO-ENV, PRIMER 6.1.5). Berdasarkan perangkat lunak EWS-3 SWJ, lokasi polikultur dan monokultur mengalami gangguan sedang, sedangkan area referensi mengalami gangguan ringan hingga sedang.

Kata kunci: Bioindikator Perairan, Stabilitas Komunitas, Gangguan Ekosistem, Akuakultur Berkelanjutan

ABSTRACT

Due to the surge in global food demand, aquaculture in Indonesia has expanded rapidly. Fish farming activities using floating net cages that neglect environmental pollution have become a significant issue in Lake Rawapening. Macrobenthic mollusks serve as valuable bioindicators for assessing disturbances in aquatic ecosystems, as they exhibit sedentary behavior, slow movement, and high sensitivity to fluctuations in water quality. This study aims to assess the structure of macrobenthic mollusk communities, environmental quality, and ecological status in the aquaculture areas of Lake Rawapening. Sediment samples were collected from polyculture, monoculture, and reference sites. A total of 9 species from 2 classes and 7 families were found at all three sites, with a low diversity index (H'), indicating limited community stability. Diversity was higher at polyculture sites compared to monoculture sites. Abiotic analysis showed that environmental parameters (temperature, pH, organic carbon, total nitrogen, phosphate) still met quality standards, although dissolved oxygen (DO) levels were low. The sediment substrate was dominated by clayey silt. Temperature was the abiotic factor most strongly correlated with mollusk abundance (r = 0.612; BIO-ENV, PRIMER 6.1.5). Based on the EWS-3 SWJ software, polyculture and monoculture sites were classified as moderately disturbed, while the reference area showed light to moderate disturbance.

Keyword: Aquatic Bioindicators, Community Stability, Ecosystem Disturbance, Sustainable Aquaculture

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1. INTRODUCTION

Waters of Rawapening span an area of 2,380 hectares, boasting significant fishery potential for local fishermen and aquaculturists engaged in fish catching and cultivation activities. The prevalent use of floating net cages for fish farming in Lake Rawapening, however, has engendered environmental concerns due to inadequate attention to eco-friendliness. Wastewater from fish rearing, comprising a substantial portion of organic matter, stems from feed remnants and fish metabolism byproducts, including urine and fesses. Undigested feed residue settling at the lake bottom undergoes microbial decomposition, exacerbating sedimentation rates and consequent siltation and eutrophication issues (Febrianto *et al*, 2016).

Aquaculture practices in floating net cages offer options of monoculture or polyculture systems. Polyculture Stratified Floating Net Cages present a more sustainable alternative to conventional methods, integrating environmental considerations and enhancing production capacity. The adaptive structure of Multilevel Floating Marine Cages ensures resilience to water level fluctuations while accommodating multiple biota species simultaneously within the same aquaculture area, without expanding spatial requirements (Putro *et al*, 2014). In aquatic ecosystems, bioindicators serve as effective tools for assessing anthropogenic impacts, embodying functional traits closely tied to specific environmental factors. Macrobenthos, residing at the aquatic bottom, represent a pertinent example of bioindicators, with mollusks being prominent soft-bodied benthic organisms in freshwater habitats. Gastropods and Pelecypoda/Bivalves, belonging to the mollusk class, exhibit sedentary lifestyles, slow mobility, and acute sensitivity to water quality alterations.

The influx of waste materials into the lake precipitates changes in physical, chemical, and biological parameters, profoundly affecting aquatic environments and biota. Elevated pollution levels diminish mollusk populations and diversity, contingent upon sediment texture, organic matter content, and physicochemical parameters conducive to mollusk growth and development (Riniatsih *et al*, 2009). Sediment characteristics exert significant influence on mollusk morphology, behavior, and nutritional ecology, as these organisms adapt to substrate types, modulating feeding strategies and physiological responses to temperature, salinity, and chemical variables (Razak, 2002). Gastropods and Bivalves adeptly thrive in fine sediment environments, leveraging specialized physiological adaptations to muddy substrates.

Numerous studies have examined the long-term effects of aquaculture activities on air quality and mollusk community structure. Research can investigate how aquaculture practices on Danau Rawapening affect the health of the ecosystem and mollusk communities (Zhao *et al,* 2019). To understand the impact of aquaculture on the aquatic ecosystem, this study focuses on analyzing the structure of macrobenthic mollusk communities, water conditions, and environmental quality status in aquaculture areas of Lake Rawapening. The findings of this research are expected to provide guidance for more sustainable and environmentally friendly fish farming management practices.

2. METHODS

2.1. Time and Location of Research

The research was conducted from October to December 2021 in the floating net cage cultivation area of Lake Rawapening, situated in Asinan Village, Bawen District, Semarang Regency. The study encompassed three distinct locations: the polyculture fish farming area, the monoculture fish farming area, and the non-cultivation area designated as the reference site. Within each location, three sampling stations were established, spaced 5 meters apart. Sampling occurred thrice at each station, with one-month intervals between sessions. The sampling process, employing the purposive sampling method, was conducted at three different locations to ensure representation of the research area (Syahminan *et al*, 2015).

Location I is situated within the polyculture-level floating net cage aquaculture area, positioned at coordinate point 7°16'13.499''S-110°26'18.178''E. Tilapia and catfish are the species cultivated in this area. Location II, located approximately 1 kilometer from Location I, lies within a monoculture fish farming area at coordinates 7°16'46.652''S-110°26'11.598''E. Tilapia is the primary species cultivated in this area. Location III serves as a reference area and is positioned at coordinates 7°17'19.414''S-110°26'8.856''E, also within 1 kilometer of Location II. Situated in the midst of Lake Rawapening, this location represents a non-cultivation area.

2.2. Sampling

Water quality measurements were conducted in situ using a Horiba U-50 water checker, which directly measures and records digital information. The process involves inserting the probe into the lake water at each station until fully submerged. The submerged probe is left to stabilize for a few minutes until digital measurement results are consistent and stable. Recorded data are either stored or directly recorded. Parameters measured at the research location included temperature, pH, dissolved oxygen (DO), and total dissolved solids (TDS).

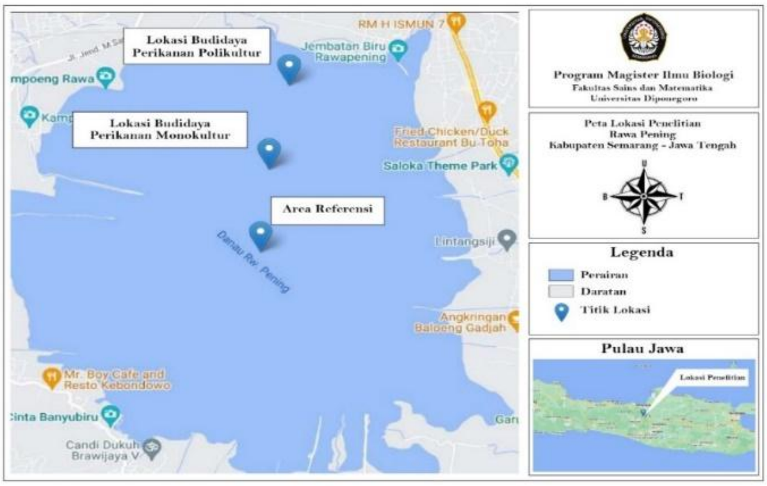

Figure 1. Map of Sampling Locations for Monoculture, Polyculture and Lake Rawapening Reference Areas, Semarang

Sediment collection was performed using an Ekman grab tool at each station, with a size of 250 cm2 and attached to a long rope. Mollusk sampling involved extracting sediment and biota samples using an Ekman grab (Susantoro *et al*, 2019). The Ekman grab was released into the water body, reaching depths of approximately ±3-4 meters, suitable for collecting sand, gravel, muddy, or clay sediment samples (Putro *et al*, 2014). Sediment samples obtained were placed in sample boxes and treated with 4 caps of 10% formalin for fixation, along with 2 caps of 70% ethanol, and labeled with the study location and sampling time. Subsequently, all samples were transported to the Ce-MEBSA Laboratory, UPT Diponegoro University Semarang, for sorting, identification, and data analysis.

3.3. Data Analysis

The identified mollusks were assessed for species number, density, and abundance. Mollusk diversity was evaluated using the Shannon-Wiener index, while evenness was analyzed using the evenness index, and species dominance was determined using the Simpson dominance index. To conduct multivariate analysis of the relationship between abiotic and biotic variables, species abundance data were correlated with abiotic variables such as temperature, pH, DO, TDS, substrate grain size, and organic matter content. The analysis was performed using the BIO-ENV method in PRIMER V.6.1.5 software, with data transformed into Log (X+1) (Clarke & Gorley, 2006). This analysis identifies the abiotic factors most influencing the presence of macrobenthos (Sharani et al., 2018; Putro et al., 2019).

The water environmental quality status was determined using EWS-3 SWJ software, which integrates biotic and abiotic data, along with diversity (H'), evenness (e'), and dominance (c) indices to trigger the Early Warning System (BIC, 2021). The results indicate the level of environmental disturbance (light, moderate, or high) and dominant taxa, while also providing recommendations for recovery actions or the temporary suspension of aquaculture activities.

3. RESULTS AND DISCUSSION

3.1. Abundance of Molluscs

The abundance of molluscs in the Rawapening Lake conducted in three different locations, namely the polyculture area, monoculture area, and reference area in Lake Rawapening. A total of 9 species were found which were divided into 7 families and 2 different classes with an individual abundance of 4.178 individuals.m^{-2} can be seen in the table 1. Based on the observations, the abundance of individuals at the polyculture site was 622 individuals.m^{-2}, monoculture sites 1.511 individuals.m^{-2} and reference areas 1.955 individuals.m^{-2}. Gastropods class in mollusc species are more dominant than bivalve class. This is in accordance with the statement of Sarong (2015) which states that gastropods are the class with the highest species or diversity in the phylum Molluscs, gastropods can live in all areas such as Antarctica and in almost all aquatic habitats including rivers, lakes, swamps and other aquatic habitats, while bivalves are less adaptive and highly dependent to environmental parameters. The most abundant species among several species are consisted of 2 gastropods and 1 bivalve: *Filopaludina javanica (*gastropods*)* are abundant in three locations*, Melanoides tuberculate* (gastropods) are only abundant in reference area, while *Pilsbryoconcha exilis* (bivalves) are available in three areas. *F. javanica* can be found abundance in November. *F. javanica* is a gastropod that consumes a breakdown of organic material (Lailiyah, 2021), and also well known to accumulate heavy metals such as Pb and Cd in ecosystems. Residential and agriculture areas are contributed to the concentrations of heavy metals (Priawandiputra, 2020). According to research in Lailiyah (2021) shows that *F. javanica* can reduce the levels of organic matter up to 92% (68.75 mg/L to 5.31 mg/L) and goes to level that meets the water quality standards for 12 hours work.

Table 1. Composition of Mollusc Abundance in Polyculture, Monoculture, and Reference Areas

No	Class	Family	Species	Location								
				Polycultur			Monocultur			Reference		
				Oct	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec
1	Bivalvia	Unionidae	*Pilsbryocncha exilis*	89	0	0	133	133	0	133	0	0
2	Gastropoda	Viviparidae	*Filopaludina javanica*	133	133	178	0	711	133	178	844	178
		Lymnaeidae	*Lymnaea rubiginosa*	0	0	0	0	89	0	0	0	0
		Thiaridae	*Melainoides maculata*	0	0	0	0	0	0	0	0	44
			Melanoides tuberculata	0	44	0	0	89	0	44	133	44
		Ampullaridae	*Pila ampullacea*	0	0	44	89	0	0	0	133	0
			Pomacea insularum	0	0	0	0	44	0	0	0	0
		Planorbidae	*Ferrisia sp.*	0	44	44	0	0	89	0	178	0
		Pachychilidae	*Sulcospira terstudinaria*	0	0	0	0	0	0	44	0	0
Individual Abundance Number				222	222	267	222	1067	222	400	1289	267
Number of Species				2	3	3	2	5	2	4	4	3

Table 2. Shannon-Wiener Diversity Index (H'), Evenness Index (E) and Dominance Index (c) of Molluscs in the Study Area

Index	Location								
	Polyculture			Monoculture			Reference		
	Oct	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec
Diversity Index (H')	0,68	0,93	0,83	0,68	1,07	0,68	1,19	1,02	0,83
Evenness Index (E)	0,98	0,84	0,76	0,98	0,58	0,98	0,82	0,69	0,76
Dominance Index (D)	0,48	0,54	0,47	0,48	0,52	0,48	0,65	0,53	0,47

F. javanica has a filter feeder property that give them the ability to filtering organic matter. *Filopaludina javanica* is a species that adapt easily in various habitats and has a very wide distribution in freshwater (Perez, 2011). According to research in Lailiyah (2021) shows that *F. javanica* can reduce the levels of organic matter up to 92% (68.75 mg/L to 5.31 mg/L) and goes to level that meets the water quality standards for 12 hours work, *F. javanica* has a filter feeder property that give them the ability to filtering organic matter. *Filopaludina javanica* is a species that adapt easily in various habitats and has a very wide distribution in freshwater (Perez, 2011).

While *Melanoides tuberculata* are known to be invasive species, dominating in aquatic ecosystems such as rivers and lakes, supported by invasive molluscs research (Purnama, 2022) According to Raw (2016) research, invasive species causing a disadvantage to ecosystems such as native species losses, furthermore, abundance of this species could be affected economically by causing major losses on agriculture and commercial activities. *M. tuberculata* consumes periphytic, microalgae, organic particles in sediment and detritus. Reported on Raw (2016) over 60% of the total microalgal biomass were consumed by *M. tuberculata*, the feeding dynamics for *M. tuberculata* are positively correlated with temperature, as hi. The temperature will increase the consumption efficiency and gut passage time. This species is known to be a good bioindicator and heavy metal accumulator.

3.2. Diversity Index(H'), Evenness Index (E) and Dominance Index (D)

The indices calculated at the location of polyculture, monoculture and reference areas are presented as the Shannon-Wiener Diversity Index (H'), Evenness index (E) and Dominance index (c) of molluscs in the table 2. The Shannon-Wiener Diversity Index (H') values observed at the three study locations were consistently low across all periods, ranging from 0.68 to 1.19. These low values suggest an unstable condition at all stations within Lake Rawapening, indicating unfavourable or disturbed water conditions. Such instability can stem from various factors closely tied to mollusk life. Mollusk diversity in lake waters is influenced by several abiotic and biotic factors, including habitat (substrate) characteristics and water chemistry. Environmental conditions characterized by pollution tend to exhibit lower diversity (Susantoro *et al*, 2019). The highest mean diversity index value was observed in the reference area, while the lowest was in the monoculture area, suggesting that polyculture locations harbour more diverse communities compared to monoculture locations.

The Evenness Index value (e) at polyculture, monoculture, and reference areas was classified as moderate, ranging from 0.58 to 0.98. On average, the Evenness index value at polyculture locations exceeded that of monoculture locations, indicating greater stability in polyculture sites. High Evenness reflects an equal distribution of individuals among species, promoting higher survival rates, whereas low to moderate Evenness suggests unequal distribution dominated by certain species (Odum, 1993).

The Simpson Dominance index (D) values for the three sampling locations indicated low to moderate dominance, ranging from 0.48 to 0.65. No instances of high dominance were observed. However, *Filopaludina javanica* emerged as the most abundant species in both polyculture and monoculture areas, with *Pilsbryoconcha exilis* ranking as the second most abundant. In the reference areas, *F. javanica* also dominated, with *Melanoides tuberculata* as the second most abundant species. The presence of dominant species signifies differences in adaptability among species to the environment.

3.3. Physical And Chemical Factors

Physical-chemical factors measured include temperature, degree of acidity (pH), DO, TDS. Results measurements of chemical physics factors are presented in Table 3. Temperature measurements at the polyculture, monoculture, and reference areas exhibited a range of 27.32°C to 29.73°C. According to Government Regulation Number 82 of 2001, regarding water quality management and control of class II water pollution, the temperature at all three locations complies with water quality standards. Kordi *et al* (2005) note that the optimal temperature range for fish life in tropical waters falls between 28°C to 32°C, indicating that the water temperature at these locations can support aquatic life. Temperature fluctuations influence the growth of mollusks; as noted by Wagey *et al* (2017), increasing water temperature stimulates mollusk metabolism, while decreases in temperature reduce metabolic rates. Bivalves, in particular, are sensitive to temperature fluctuations, with some species only tolerating temperatures ranging from 16°C to 27°C, beyond which their survival may be impacted.

The pH values ranged from 6.81 to 8.45 across all sampling locations. Government Regulation Number 82 of 2001 specifies a pH standard for tropical waters ranging from 7 to 8.5. Although the pH value at the polyculture location in October (6.81) falls below the standard, it still supports aquatic life. Wardhana (2006) asserts that water with a pH value around 6.5 to 7.5 is considered normal and suitable for life. The optimum pH for benthic mollusks typically ranges from 6.5 to 7.5 (Alfitriatussulus, 2003).

Dissolved oxygen (DO) values at all locations ranged from 0.46 to 2.05 mg/l. Aquatic organisms generally require dissolved oxygen concentrations between 5 to 8 mg/l. The low DO values observed across all locations may be attributed to increased pollution, such as residues from water hyacinths, food remnants, and fish waste from floating net cages, along with upstream waste entering Rawapening. This leads to increased decomposition activity, accelerating the rate of dissolved oxygen consumption by decomposers (Barus *et al*, 2020).

Total dissolved solids (TDS) values ranged from 69 to 232 across all locations, meeting the quality standard set by PP No. 82 of 2001, where the Class II designation stipulates TDS values less than 1000 mg/l. The highest TDS value recorded in October may be attributed to residential, agricultural, fishery, and industrial waste, which significantly impact the ecosystem and pose risks to local health. Additionally, the revitalization efforts in October, including water hyacinth removal and sediment dredging, contributed to increased solid material content in the waters.

3.4. Content of Organic Materials

The measured organic matter content includes C-Organic, N-Total and Phosphate. Results measurements of chemical physics factors are presented in figure 2. The disparity in C-organic, total N, and phosphate yields across all sampling locations can be attributed to variations in sampling time and may also be influenced by aquaculture activities, leading to the accumulation of metabolic waste at the sampling sites. Another contributing factor to differences in organic matter content is the revitalization efforts of Lake Rawapening, including sediment dredging and water hyacinth removal. Mechanical dredging, utilizing excavators, suspends sediment particles and increases total suspended solids (TSS) or turbidity, consequently altering the concentrations of various materials stored within the sediments (Mashoreng *et al*, 2022).

C-organic content at the sampling locations ranged from 1.97 mg/l to 5.72 mg/l. The highest C-organic content was observed in the polyculture location in October (5.72 mg/l), while the lowest was in the monoculture location (1.97 mg/l). The differences in total organic carbon concentration are attributed to variations in the sources of organic matter input and total organic carbon at each sampling location (Barus *et al*, 2020). The average C-organic content in polyculture locations exceeded that of monoculture locations, likely due to the significant input of organic matter from water hyacinth plants. Madjid (2007) noted that soil organic matter primarily originates from plant organic tissue, including leaves, twigs, branches, stems, fruits, and roots, which undergo weathering and degradation into sediments.

Table 3. Mean Results of Measurement of Physical and Chemical Factors of Lake Rawapening Aquaculture Waters

Chemical Physics Parameters	Quality Standards	Location								
		Polyculture			Monoculture			Reference		
		Oct	Nov	Dec	Oct	Nov	Dec	Oct	Nov	Dec
Temperature (°C)	28-30	27,71	29,07	29,73	28,32	29,44	29,65	28,59	29,4	29,13
pH	7-8,5	6,81	7,36	8,38	7,44	7,61	8,28	7,44	7,94	8,45
DO (mg/l)	4	1,47	1,01	1,36	2,05	0,84	1,25	2,05	0,46	1,38
TDS	<1000	232	96	71	227	88	70	228	86	69

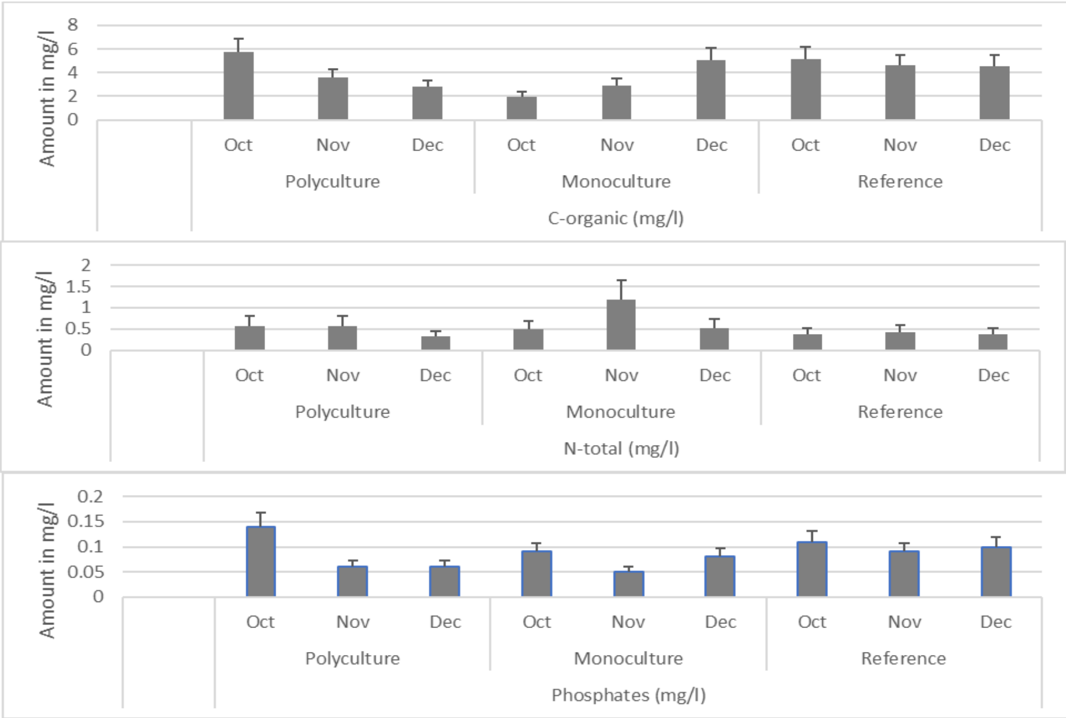

Figure 2. Organic Matter Content of Lake Rawapening Aquaculture Waters

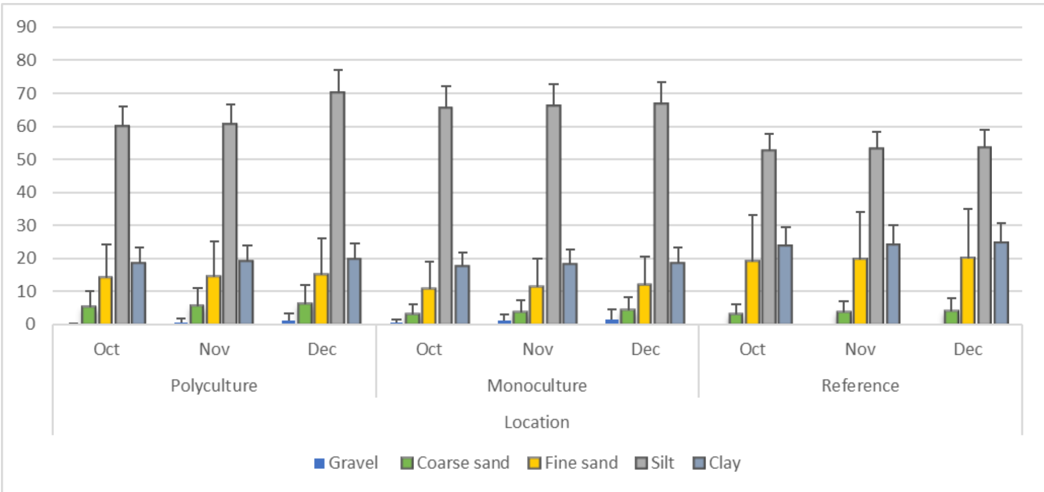

Figure 3. Lake Rawapening Substrate Grain Composition

Total N measurements at the study sites ranged from 0.32 to 1.18 mg/l. According to Republic of Indonesia Government Regulation no. 68 of 2016 concerning total N for aquaculture and the abundance of aquatic biota is 1 mg/L. The total N concentration at all locations exceeded the quality standard except at the monoculture location in November. The average concentration of total N in monoculture locations surpassed that of polyculture locations, likely due to the substantial amount of uneaten fish feed and fecal deposition. Price *et al* (2013) highlighted that floating net cages contribute nitrogen to waters through leftover feed, fish feces, and metabolic waste, leading to eutrophication and disruption of the aquatic ecosystem balance. Phosphate measurements at the study sites ranged from 0.05 to 0.14 mg/l. The highest Phosphate value was observed in the monoculture cultivation location in November (1.18 mg/l), while the lowest was in the polyculture cultivation location in December (0.32 mg/l). According to Republic of Indonesia Government Regulation Number 68 of 2016, the concentration of phosphate for fish cultivation and the abundance of aquatic biota is 0.1 mg/l. Based on these regulations, the phosphate content in all locations meets quality standards except for polyculture and reference locations in October. The average phosphate value at polyculture locations exceeded that of monoculture locations, likely due to the extensive decomposition of organic compounds from feed residues and fish farming metabolic waste. Additionally, high phosphate content may result from the discharge of domestic waste from residential areas and floating stalls around Rawapening.

Table 4. The results of the Combined Analysis of the Correlation of the Abundance of Molluscs and Physical and Chemical Factors of the Waters and Sediments

Correlation Value (r)	Coefficient of Determination (r^2)	Variable	Number of Variables
0,612	37,45%	1	1
0,548	30,03%	1,7	2
0,476	22,66%	4,6,8,10	4
0,473	22,37%	4,6,10	3
0,473	22,37%	1,4,6,10	4
0,473	22,37%	2,4,6,10	4
0,473	22,37%	4,7,10	3
0,473	22,37%	4,6,10,12	4
0,473	22,37%	4,6,10,11	4
0,471	22,18%	4,5,10,12	4

Information: 1 (Temperature), 2 (pH), 3 (DO), 4 (TDS), 5 (C-Organic), 6 (N-Total), 7 (Phosphate), 8 (Gravel), 9 (Rough sands), 10 (Fine Sand), 11 (Silt), 12 (Clay).

Table 5. Environmental Status Based on Analysis Using the EWS-3 SWJ Software

Location	Description	Environmental status
L1U1	October Polyculture	Moderately Disturbed Area
L1U2	November Polyculture	Moderately Disturbed Area
L1U3	December Polyculture	Moderately Disturbed Area
L2U1	October Monoculture	Moderately Disturbed Area
L2U2	November Monoculture	Moderately Disturbed Area
L2U3	November Monoculture	Moderately Disturbed Area
L3U1	October Reference	Moderately Disturbed Area
L3U2	November Reference	Moderately Disturbed Area
L3U3	December Reference	Lightly Disturbed Area

3.5. Composition of Substrate Granules

The composition of the sedimentary substrate grains includes gravel, fine sand, coarse sand, silt and clay. Rawapening Lake substrate grain composition can be seen in figure 3. The three study locations have a clay silt substrate type because the silt fraction dominates and is followed by the clay fraction. The substrate in the form of silt at the three sampling locations has a range of 53% – 66.08%. The highest silt composition was found in the monoculture location of 66.08% and the lowest in the reference location of 54%. The average high content of the silt fraction at the three sampling locations also contributed to the high organic matter content. This is because substrates that have finer grains are more able to accumulate organic matter. According to Usro (2013), sediments with a clay texture have a large surface area so they have a high ability to absorb nutrients and retain water, so that soils with a fine texture will be more active in reactions. chemicals than coarse-textured soils.

The substrate in the form of clay at the three sampling locations has an average of 20.33%. While the substrate in the form of fine sand and coarse sand has an average of 15% and 4.2%. The ability of clay to store organic matter is greater than that of sand because clay substrates have tighter pores so that organic matter settles more easily than sand substrates where the particles and pores are larger which causes organic matter to easily be carried away by currents. The substrate in the form of gravel has the smallest percentage at each station with an average of 0.54%. Rawapening lake waters are lake-type waters that do not have strong water currents so that the particles that settle in the sediment are fine particles. According to Boggs (2013), the deposition of silt particles on the bottom of the waters depends on water currents. If the water currents are strong, the particles that settle are large and if the water currents are not strong, the particles that settle will have a smaller size.

3.6. Correlation Between Abiotic and Biotic Factors

The biotic variables analysed were species abundance values and then related to abiotic variables including temperature, pH, DO, TDS of substrate grains and organic matter content using BIO-ENV in PRIMER V.6.1.5 software. The data generated by BIO-ENV is in the form of abiotic factors that influence the presence of mollusc.

Based on Table 4, the abundance of mollusks exhibits the strongest correlation with temperature, with a correlation value of (r = 0.612) and a coefficient of determination of r^2 = 37.45%. Temperature plays a critical role in shaping the distribution, species composition, and behavior of mollusks. It can restrict the geographical range of macrobenthic animals, with the optimal temperature for macrobenthos growth typically ranging from 25°C to 31°C. Several mollusk species thrive best at around 20°C, and temperatures exceeding this threshold can lead to decreased metabolic activities. Another variable showing a significant correlation (r = 0.548) with mollusk abundance is phosphate levels. Organic phosphate, derived from the metabolic waste of aquatic animals, contributes to elevated dissolved phosphate levels in water, which in turn supports aquatic plant growth.

Additionally, fine sand substrate is identified as another variable correlated with mollusk abundance. Fine sand substrates consistently appear in correlation analyses, regardless of their specific properties and supporting composition. Muddy and sandy substrates are highly preferred by mollusks, as these substrates are favored by most benthic organisms over other substrate types.

3.7. Environmental Status of Lake Rawa Pening Aquaculture Area

The data generated from the EW-3 SWJ software shows the level of disturbance in aquatic environments such as Lightly Disturbed Areas, Moderately Disturbed Areas and Highly Disturbed Areas and which taxa are dominant at the study site. In addition to the level of environmental disturbance and dominant taxa, the EW-3 SWJ software also provides suggestions or recommendations in the form of recovery actions and temporary suspension of aquaculture activities.

Based on Table 5, both the polyculture and monoculture locations experienced a moderate level of environmental disturbance from October to December. This disturbance is attributed to aquaculture activities generating organic waste, including metabolic waste and feed residue. According to Hoogsteen *et al* (2018), the decomposition of organic matter in the waste consumes oxygen in the water and releases acidic carbon dioxide, leading to a decrease in water pH Further investigation and regular biomonitoring are necessary to identify the factors contributing to environmental disturbances and decreased activity. In October and November, the reference area exhibited moderately disturbed environmental status, whereas in December, the disturbance level decreased to mild.

The analysis of mollusk diversity, which yielded low values, suggests that all sampling locations are in relatively unstable conditions. This low value indicates ecological and environmental pressure on the water bodies. Mollusk existence is influenced by various aquatic environmental factors. Measurement of abiotic physio-chemical factors and organic matter content was conducted to assess environmental conditions. Results of chemical-physical factor measurements, including temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and organic matter content, indicated values within the tolerance range for mollusks. Despite the absence of water pollution based on environmental measurements, research on toxic content such as heavy metals and other contaminants is warranted.

Pollution arises from both natural processes and community activities surrounding the lake, disrupting the ecosystem. Human activities, such as littering, domestic waste disposal, and agricultural and fishery waste, interfere with mollusk growth and negatively impact ecosystem health. This pollution renders the ecosystem inhospitable for many organisms to thrive. The high level of contaminants in the waters results in diminished aquatic biota and an increase in populations of species tolerant to adverse conditions.

4. CONCLUSIONS

Based on the research findings, it can be concluded that there are a total of 9 mollusk species belonging to 2 families found across the three research sites. The dominant species in the polyculture, monoculture, and reference locations are *Filopaludina javanica, Fer'isia sp, Pilsbryoconcha exilis*, and *Melanoides tuberculata*. The diversity index (H') at all locations falls within the low category, indicating low community stability. However, diversity is higher in polyculture locations compared to monoculture locations, suggesting that polyculture sites have more stable communities. This implies that implementing polyculture with multilevel floating net cage systems can help reduce potential environmental impacts from aquaculture activities.

Chemical-physical measurements such as temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and organic matter content remain within tolerable ranges for mollusks. The sediment substrate at all three locations is predominantly clay silt, with silt being the dominant fraction followed by clay. Correlation analysis indicates that mollusk abundance is strongly correlated with temperature, phosphate levels, and fine sand substrate. The environmental status of both polyculture and monoculture locations indicates a moderate level of environmental disturbance, while the reference area shows a moderate to mild disturbance level.

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