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Bivalves Diversity and Abundance in the Coastal Waters: An Environmental Pollution Monitoring Measure

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Abstract | This study aims to determine the species, diversity, abundance, and the correlation between water physical-chemical factors and the number of bivalves found. It serves as one of the approaches to biodiversity conservation, environmental quality monitoring, and the sustainable management of aquatic resources, particularly in monitoring the condition of water bodies resulting from river water pollution caused by industrial waste and household waste. There were three bivalve sampling stations, each with three sub-stations, which were purposively determined in Banyuurip Village, Ujungpangkah District, Gresik Regency, Indonesia. Sampling was done by dredging using a *garit* (trawl). The data analysis in this study included the Shannon index, dominance index, species abundance, and Pearson correlation analysis. The results showed that 10 species of bivalves had a diversity index of 2.019 at Station 1 (mangrove area) and 2.246 at Station 2 (marine intertidal zone). In contrast, Station 3 [*Perna viridis* (Linnaeus, 1758). rack culture area] amounted to 2.226. The dominance index value of Station 1, amounted to 0.1703, Station 2, amounted to 0.1108, and Station 3, amounted to 0.1136. The highest abundance of bivalve species was obtained by *Anadara granosa* (Linnaeus, 1758), with a value of 449.3 ind. m^{-3}. The pH ranged from 7.13 to 7.87, temperature from 27 °C to 27.6 °C, salinity from 14.03 ‰ to 17.67 ‰, and dissolved oxygen (DO) from 5 mg L^{-1} to 5.9 mg L^{-1}. Correlation analysis results showed that pH was strongly negatively correlated with *A. consociata* (Gray, 1847) (121), temperature was strongly positively correlated with *Paphia undulata* (Born, 1778) (91), salinity was strongly negatively correlated with *A. consociata* (Gray, 1847) (121), and DO was strongly negatively correlated with *A. granosa* (Linnaeus, 1758) (184). Future research is encouraged to expand the spatial and temporal coverage of sampling to obtain a more holistic understanding of bivalve diversity, population dynamics, and their ecological interactions with environmental parameters. Additionally, research efforts should address aspects of food safety by minimizing the presence of metals and microplastics, aligning with Sustainable Development Goals (SDGs) 3, 6, and 14. This is particularly important since bivalves represent a potential alternative source of essential amino acids and omega-3 fatty acids for human nutrition.

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Introduction

Bivalves are filter feeders, organisms that obtain food from filtering plankton, suspended particles, and organic matter. The ability to filter water and suspensions and bivalves can contribute to a decrease in the concentration of dissolved particles, which can simultaneously increase water clarity (Rong *et al*., 2021). The increase in water clarity results from a reduction in total water column nutrients or excess particulate organic matter from the filtering process carried out by bivalves (Rosa *et al*., 2018).

Bivalves ecologically act as predators, detritivores, prey, and recyclers of organic matter in the ecosystem. Bivalves have a long-life cycle and limited movement so that these organisms can accumulate pollutants around them. This ability also makes bivalves very sensitive to anthropogenic disturbances and natural processes, which directly impact the physiological process, behavior, and mortality of bivalves. Until now, several studies and monitoring of environmental changes have been carried out using bivalves, such as *Mytilus galloprovincialis* (Lamarck, 1819) and the genus Perna (Chahouri *et al*., 2023).

Monitoring environmental change can be known through bivalve diversity (Berliana *et al*., 2024). Diversity can be measured using a diversity index, which is a quantitative analysis used to estimate water quality, indicate the presence of a stable community, and determine community composition in relation to productivity and conservation (Bahar and Veriyani, 2021; Oktivana, 2023). The assessment of diversity can be complemented with abundance analysis to determine the number and condition of species within a specific area (Sandika, 2021). Abundance is the number of species found in an area (Zakhera, 2010). By calculating abundance, it can be seen that the total number of individuals of a species is equal to all individuals contained in a certain area in the community (Yuliana *et al*., 2020).

This study was conducted in the coastal waters of Banyuurip Village, Ujungpangkah District, Gresik Regency, Indonesia, due to its significant fisheries potential, supported by extensive coastlines and aquaculture areas (Sambah *et al*., 2019). Banyuurip is one of the leading regions in fisheries, particularly bivalves, which are obtained through capture and cultivation. The area is also affected by human activities such as ports and aquaculture and the presence of competitor species that may influence bivalve diversity and abundance (Aminin *et al*., 2022; Firmani and Safitri, 2023). This study aims to determine the species, diversity, abundance, water physical-chemical factors, and the correlation between water physical-chemical factors and the number of bivalves as a filter-feeding organism that plays crucial role in aquatic ecosystem. These efforts support the achievement of the Sustainable Development Goals (SDGs), particularly Goal 3 (Good health and well-being), Goal 6 (Clean water and sanitation), and Goal14 (Life below water).

Materials and Methods

Research time and location

This research was conducted from October 2023 to April 2024. Bivalve sampling and measurement of aquatic physical-chemical factors were carried out in the coastal waters of Banyuurip Village, Ujungpangkah District, Gresik Regency, East Java, Indonesia (coordinate: S 6°54'31.644", E 112°31'38.9604"). In contrast, bivalve samples were identified at the Optical Laboratory of the Biology Study Program, Faculty of Science and Technology, Maulana Malik Ibrahim State Islamic University Malang, East Java, Indonesia (coordinate: S 7°57'5.94", E 112°36'27.7776").

Determination of sampling stations.

Sampling stations were determined purposively, while bivalve samples found were taken randomly without being grouped by size. As stated by Fuad *et al*. (2019), purposive determination of sampling locations is carried out on marine biota whose samples are difficult to find at random points. Station 1 was in the mangrove area (coordinate: 6°54′17.11″ S, 112°31′43.71″ E), Station 2 was in the marine intertidal zone (coordinate: 06°52′18.84″ S, 112°29′41.19″ E), and Station 3 was in the rack culture area green mussel [*Perna viridis* (Linnaeus, 1758)] (coordinate: 06°52′18.84″ S, 112°29′41.19″ E) (Figure 1).

Sampling technique.

Sampling was carried out with a traditional fishing gear named *garit* measuring 1.3 m × 0.7 m × 0.45 m at each station. *Garit* is a traditional fishing gear commonly used by local fishermen to catch bivalves (Desrita, 2019) (Figure 2). *Garit* was lowered to the bottom of the water and then moved using a boat to get bivalve samples. The *garit* sampling technique can be done three times replication in one sampling with a distance of ± 10 m for each replication (Ginting *et al*., 2017). The excavated substrate attached to the bivalve sample is cleaned and filtered, the whole number of bivalves is taken 1 to 3 individuals to be put into plastic clips that have been given 70 % alcohol and labeled, then put into a cool box as a sample preservation process before identification in the laboratory (Bening and Purnomo, 2019; Khouw, 2009).

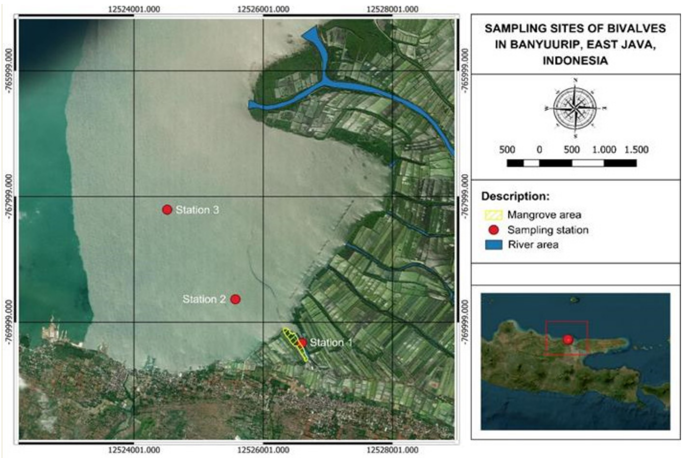

Figure 1: *Sampling sites of bivalves in banyuurip, east java, indonesia*

Figure 2: *Traditional fishing gear named garit (*Desrita *et al*., 2019*).*

Physical-chemical factors

Measurements of the physical-chemical factors of the waters were carried out at each sampling station. Parameters measured directly in the field are temperature and salinity. Temperature and salinity parameters were measured with a multitest checker, while other parameters, such as pH and Dissolved Oxygen (DO), were analyzed at the Jasa Tirta I laboratory (coordinate: S 7°57'56.0016", E 112°37'7.8672") Laboratory analysis was carried out with 500 mL water samples collected from each research station. pH was measured using a pH meter, and Dissolved Oxygen (DO) was measured using the APHA 4500-O-G-2017 method.

Data analysis

Analysis of Shannon index, dominance index, diversity T-test and Pearson correlation was carried out using PAST 4.03. The abundance of species can be calculated using the formula of Fachrul (2007), which is on Equation (1).

$$K = \frac{ni}{A}$$

Description:

K : species abundance (indiv. m^{-3})

ni : number of individuals of the i-th species

A : total observation area (m^3)

Results and Discussion

Bivalves diversity and dominance index

The results of the identification of bivalve species at all data collection stations show there were 10 species of bivalves from three orders, four families, and eight genera in the coastal waters of Banyuurip Village, Ujungpangkah District, Gresik Regency, East Java, Indonesia. These species include *Placuna placenta* (Linnaeus, 1758), *Anadara granosa* (Linnaeus, 1758), *Anadara consociata* (E. A. Smith, 1885), *Barbatia barbata* (Linnaeus, 1758), *Periploma planiusculum* (G. B. Sowerby I, 1833), *Meretrix meretrix* (Linnaeus, 1758), *M. lyrata* (G.B. Sowerby II, 1851), *Paphia undulata* (Born, 1778), *Circe scripta* (Linnaeus, 1758), and *Dosinia crocea* (Deshayes, 1853). Based on Table 1, bivalve species found at each station have a diversity index (H') classified as medium and a dominance index (D) classified as low.

The highest diversity index (H') value obtained by Station 2 (marine intertidal zone) is 2.246, which is classified into the medium diversity category. The diversity index (H') at Station 2 was followed by a low dominance index (D) among the three stations. Fuad *et al*. (2019) stated that if the dominance index is low, it can be concluded that the community in the ecosystem is evenly distributed or the ecosystem is stable. Namely, the number of individuals for each species is the same or has a difference that is not too noticeable.

A medium diversity index indicates the ecosystem remains quite stable for bivalve life. The location of the station is quite far from anthropogenic activities, in contrast to Station 1, which is close to the shipyard, dock, and aquaculture activities, as well as Station 3, which is an area with high exploitation rates. Huang *et al*. (2023) stated that overexploitation of bivalve organisms can affect bivalve species' diversity, distribution, and rarity. In addition, the existence of stressors originating from anthropogenic activities can also cause a decrease in the diversity, distribution, and rarity of bivalve species in waters.

Table 1: *Analysis of bivalve communities found in the coastal waters of banyuurip, East java, Indonesia*

No.	Variables	Mangrove area	Intertidal zone	Perna viridis rack culture area
1.	Number of individuals	228	530	347
2.	Number of species	10	10	10
3.	Shannon (H') index	2.019[a]	2.246[b]	2.226[b]
4.	Dominance (D) index	0.1703[a]	0.1108[a]	0.1136[a]

Description: Different notation denote significant difference in T-test ($p < 0.05$)

Bivalve abundance

The results showed that there were 10 species of bivalves from three orders, four families, and eight genera in the coastal waters of Banyuurip Village, Ujungpangkah Subdistrict, Gresik Regency, East Java, Indonesia with a total of 1,105 individuals (Table 2).

The bivalve species with the highest abundance was *A. granosa*. *A. granosa* was found in as many as 184 individuals with an abundance of 449.3 ind. m^{-3}. This species is the most abundant bivalve because it has a high tolerance range in environments with highly fluctuating physical-chemical factors, such as pH, temperature, tides, DO, and salinity. Therefore, this species is easy to find even in unfavorable water conditions. According to some studies, this bivalve species is also resistant to higher predator pressure than other Anadara genera. In addition, *A. granosa* can live in littoral zones that are completely dry at low tide. Generally, *A. granosa* is found naturally in extensive mudflat zones with landward boundaries with salinities reaching less than 30 ‰ (Khalil, 2016).

granosa also has a reproductive cycle that lasts throughout the year, with female individuals that can produce 518 400 to 2 313 200 eggs during spawning (FAO, 2024). According to Efriyeldi and Kurniawan (2023), the larval stage in *A. granosa* is very short, namely 1 mo. Several other species take up to several months before reaching the veliger stage and attaching or burrowing into the substrate. Blood clam populations can be more abundant at a site because new individuals are added monthly due to the relatively rapid reproductive and life cycles. The larva in the tropics can be constant throughout the year as temperature and seasonal conditions do not change significantly.

Zarkasyi *et al*. (2016) reported that the bivalve community in the intertidal zone of Ujung Pangkah consisted of nine species from seven genera, five families, and four orders, dominated by *M. meretrix*

Table 2: *Abundance of bivalve species in the coastal waters of banyuurip, East java, Indonesia*

No.	Species	Mangrove area (indiv. m^{-3})	Intertidal zone (indiv. m^{-3})	P. viridis rack culture area (indiv. m^{-3})	Total (indiv. m^{-3})
1.	*Placuna placenta* Linnaeus, 1758.	41.5	134.3	97.7	273.5
2.	*Anadara granosa* Linnaeus, 1758.	175.8*	197.8*	75.7	449.3*
3.	*Barbatia barbata* Linnaeus, 1758.	90.4	149	107.4	346.7
4.	*Periploma planiusculum* G.B. Sowerby I, 1833.	85.5	175.8	105.0	366.3
5.	*Paphia undulata* Born, 1778.	36.6	61.1	124.5*	222.2
6.	*Anadara consociata* E. A. Smith, 1885	24.4	15.4	119.7	295.4
7.	*Circe scripta* Linnaeus, 1758.	26.9	85.5	46.4	158.7
8.	*Meretrix meretrix* Linnaeus, 1758.	31.7	149	90.4	271
9.	*Dosinia crocea* Deshayes, 1853.	26.9	73.3	53.7	153.8
10.	*Meretrix lyrata* G.B. Sowerby II, 1851.	17.1	117.2	26.9	161.1
Total (indiv. m^{-3})		556.8	1 294.3*	847.4	2 698.4

Description: (*) indicates the highest value *yellow*, *M. lamarckii*, and *P. undulata*. The community showed a clustered distribution with low diversity and moderate evenness, mainly influenced by CO_2, salinity, water temperature, depth, and light. Compared to our study, both indicate that the bivalve community is relatively stable, although diversity and dominance vary with location, dominant species, and environmental conditions.

Physical-chemical factors of waters

The physical factors of the waters analyzed in this study are temperature, while the chemical factors analyzed include pH, salinity, and Dissolved Oxygen (DO). The results of the measurement of the physical-chemical factors of the waters were then compared with the quality standards of seawater for marine biota listed in Appendix VIII of Government Regulation Number 22 of 2021 concerning the Implementation of Environmental Protection and Management (Table 3).

Table 3: *Results of the analysis of physical-chemical factors in the coastal waters of Banyuurip, East Java, Indonesia*

No.	Physico-chemical factors of waters	Mangrove area	Intertidal zone	Perna viridis rack culture area	Quality standards*
1.	pH	7.87	7.18	7.13	7 to 8.5
2.	Temperature (°C)	27	27.2	27.6	28 to 32
3.	Salinity (‰)	17.67	14.37	14.03	33 to 34
4.	Dissolved oxygen (DO) (mg L^{-1})	5.2		5.9	> 5 mg L^{-1}

Description: (*) seawater quality standards for marine biota in Appendix VIII of Government Regulation – Republic of Indonesia, No. 22 of 2021

The measurement results of physical-chemical factors that meet the quality standards based on Government Regulation Number 22 of 2021 are pH, temperature, and DO. The degree of acidity (pH) at the station shows a number that still meets the quality standards, so the pH is still considered good for the survival of marine biota, according to Government Regulation No. 22 of 2021 concerning seawater quality standards, pH must be 7 to 8.5 or neutral. The temperature in these waters is classified as good for the survival of marine biota because it does not exceed the quality standards; if the temperature is too high, according to Binnaser (2021), it will affect metabolism. DO at the research site still tends to meet quality standards. DO in waters must be more than 5 mg L^{-1} to allow biota to live. DO is due to the importance of oxygen for marine biota to respire (Mahaffey *et al*., 2023).

Salinity is below the seawater quality standard based on Government Regulation Number 22 of 2021, which is 14.03 ‰ to 17.67 ‰ The optimum salinity value based on Government Regulation Number 22 of 2021 is 33 ‰ to 34 ‰. The low salinity is presumed to be caused by rainy season which happened in November until February. In the study area, it is reported that the rainy season occurs from November to February, which causes more fresh water to enter the sea (The Banyuurip Village Government, 2024). As stated by Fu *et al*. (2020), salt levels in the sea can change with seasonal changes and generally decrease during the rainy season. In addition, Patty *et al*. (2020) added that water evaporation, water circulation patterns, rainfall, and river water input influence fluctuations in marine waters' salinity values.

Table 4: *Correlation of chemical physics factors of waters with the number of bivalve individuals with the number of bivalve individuals*

Species	Physico-chemical factors of waters			
	pH	Temperature	Salinity	DO
Placuna placenta Linnaeus, 1758.	-0.89466	0.43895	-0.8836	-0.092131
Anadara granosa Linnaeus, 1758.	0.40267	-0.87608	0.42467	-0.99905
Barbatia barbata Linnaeus, 1758.	-0.6821	0.097242	-0.66423	-0.43433
Periploma planiusculumG.B. Sowerby I, 1833.	-0.62103	0.016814	-0.60191	-0.50542
Paphia undulataBorn, 1778.	-0.75556	0.99814	-0.77117	0.88438
Anadara consociata E. A. Smith, 1885	-0.95443	0.57656	-0.94694	0.067767
Circe scripta Linnaeus, 1758.	-0.71497	0.14286	-0.69787	-0.39249
Meretrix meretrix Linnaeus, 1758.	-0.83422	0.32733	-0.82065	-0.2116
Dosinia crocea Deshayes, 1853.	-0.88083	0.41176	-0.86914	-0.122
Meretrix lyrata G. B. Sowerby II, 1851.	-0.52414	-0.10136	-0.50341	-0.60377

Description: Bold numbers indicate the highest value

Correlation of chemical physics factors of waters with the number of bivalve individuals with the number of bivalve individuals

Correlation analysis between physical-chemical factors of waters and the number of individuals of bivalve species is important to know how physical-chemical factors of waters affect the presence of certain bivalve species in these waters. The physical-chemical factors correlated in this study are pH, temperature, salinity, and Dissolved Oxygen (DO). The results of the correlation analysis will show a positive or negative correlation (Table 4).

The results of the correlation analysis show that the pH parameter is strongly negatively correlated with *A. consociata*. pH is related to the high and low levels of calcium; too high a pH can reduce calcium content so that the calcification process can be disrupted. Therefore, bivalves generally have an optimum pH of 7 to 8.5. Okoye *et al*. (2022) state that hydrogen ion concentration (pH) is a parameter that affects aquatic organisms' distribution, growth, metabolism, and composition.

Temperature is strongly positively correlated with *P. undulata*. Changes in ambient temperature can change the metabolic rate of marine organisms. Zhang *et al*. (2022) also suggested that 20 °C to 30 °C is the optimum temperature for *P. undulata*. The temperatures that are too high (> 34 °C) can cause a decrease in growth rates by increasing the respiration rate for metabolic processes.

Salinity is strongly negatively correlated with *A. consociata*. A decrease followed an increase in salinity values in the water in the number of individuals of the species. According to Wang *et al*. (2017), changes in salinity can disrupt the osmotic balance of mussels, which in turn also has an impact on the amount of energy needed in the osmoregulation process. Each bivalve species has a different salt tolerance influenced by genetic factors and environmental conditions, including *A. consociata*.

Dissolved Oxygen (DO) is strongly negatively correlated with *A. granosa*. According to Ibrahim *et al*. (2022), the negative correlation between dissolved oxygen and the number of bivalve individuals can be related to competition. Aquatic organisms other than bivalves tend to choose water areas with higher dissolved oxygen levels, as well as the bivalves. Therefore, an increase in dissolved oxygen levels in the water can increase competition between organisms so that the number of individual bivalves, especially *A. granosa*, which is abundant in these waters, will decrease.

Conclusions and Recommendations

Based on research conducted in the coastal waters of Banyuurip Village, Gresik Regency, it is known that there are 10 species of bivalves, including *Placuna placenta* (Linnaeus, 1758), *Anadara granosa* (Linnaeus, 1758), *Anadara consociata* (E.A. Smith, 1885), *Barbatia barbata* (Linnaeus, 1758), *Periploma planiusculum* (G. B. Sowerby I, 1833), *Meretrix meretrix* (Linnaeus, 1758), *M. lyrata* (G.B. Sowerby II, 1851), *Paphia undulata* (Born, 1778), *Circe scripta* (Linnaeus, 1758), and *Dosinia crocea* (Deshayes, 1853). The Shannon-Wiener diversity index (H') was classified as medium, and Simpson's dominance index (D) as low. The values of physical-chemical factors in waters that meet the quality standards of Government Regulation Number 22 of 2021 are pH, temperature, and DO, while salinity does not meet the quality standards. The correlation analysis results show that the pH parameter is very strongly negatively correlated with *A. consociata* (E. A. Smith, 1885), temperature is very strongly positively correlated with *P. undulata* (Born, 1778), salinity is very strongly negatively correlated with *A. consociata* (E. A. Smith, 1885), and Dissolved Oxygen (DO) is very strongly negatively correlated with *A. granosa* (Linnaeus, 1758).

Future research

Future research should broaden the spatial range and temporal scale of sampling to capture variations across habitats and over time. Likewise, it should be supplemented with food safety observation variables. Bivalves are a rich source of protein (Raut *et al*., 2023, 2025), particularly essential amino acids, including glutamate, asparagine, alanine, lysine, leucine, and isoleucine (Setyobudi *et al*., 2023, 2024), which are contained by bivalves (Pertiwi *et al*., 2025; Tabakaeva *et al*., 2018). Vitamin B12, vitamin D, mineral (Iron and Zinc), Omega-3 and Omega-6 are also found in bivalves (KarSoon *et al*., 2020; Raut *et al*., 2025; Tan *et al*., 2025).

However, bivalves have been reported to be contaminated with heavy metals and microplastics, including in China (Xiao-Dong and Jian-Long, 2023), India (Aswathy *et al*., 2022), and Indonesia (Asadi *et al*., 2022; Bimantara, 2018; Rahman *et al*., 2025; Soegianto *et al*., 2021; Werorilangi *et al*., 2025). Specifically, microplastics, as a "new pollutant", should be of concern because they have been stated to harm the health of experimental animals (Garfansa *et al*., 2024; Hermayanti *et al*., 2024, 2025).

Bivalves play an essential role in maintaining ecosystem balance. Bivalves can serve as an early warning system, act as key regulators of ecosystem stability, and provide vital ecosystem services whose sustainability must be preserved, owing to their capability to absorb excess nutrients and remove waste derived from fed aquaculture. This approach may provide economic benefits to farmers through potential compensation for nutrient removal, implemented via nutrient trading schemes analogous to existing carbon trading systems (van der Schatte Olivier *et al*., 2020).

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Novelty statement

This study represents the first bivalve research conducted in the coastal waters of Banyuurip Village, Gresik Regency, East Java, Indonesia (coordinate: S 6°54'31.644", E 112°31'38.9604"). Previous studies, such as Bimantara (2018), have primarily focused on species dominance, diversity, and heavy metals (Pb) related to bivalves. In contrast, this study also analyzes bivalve abundance and correlates bivalves to environmental factors to identify the most abundant species in the location and explore a deeper understanding about environmental factors relating to each bivalve species. The diversity and abundance of bivalve populations serves a fundamental bio-indicator that significantly contributes to achieving the Sustainable Development Goals (SDGs), specifically Goal 3 (good health and well-being), Goal 6 (clean water and sanitation), and Goal 14 (life below water). Bivalves possess a filter-feeding capacity that naturally functions as a water purification system, consequently fostering clear and healthy aquatic ecosystems. A decline in bivalve diversity can indicate environmental degradation and an increase in pollutant levels, including emerging threats such as microplastics. This correlation specifically pertains to Goal 3 because contaminated bivalves can transfer toxins into the human food chain, while sustainable, low-pollutant bivalve populations ensure food security and support the livelihoods of coastal communities, thereby contributing to Goal 1 (no poverty) and Goal 2 (zero hunger).

Authors Contribution

Titan Memory Yuhana: Conceptualized and designed the study, elaborated on the intellectual content, performed a literature search, prepared the manuscript, and revised it.
Dwi Suheriyanto: research supervision and elaborated the intellectual content
Zane Vincēviča-Gaile and Ivar Zekker: Review the manuscript
All authors have read and approved the final manuscript.

Generative AI and AI-assisted technology statement
The authors stated that they didn't use generative AI and AI-assisted technology in preparing this manuscript

Conflict of interest
The authors have declared no conflict of interest

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