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Analysis of Plankton Species Abundance and Water Quality Parameters Before and After Fish Shelter Deployment in Nepa Waters, Sampang Regency, Madura

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Abstract

The construction of fish shelters is one of the efforts to support the achievement of Sustainable Development Goals (SDGs) point 14: Life Below Water, which emphasizes the importance of preserving marine ecosystems and ensuring the sustainable use of aquatic resources. This study aims to analyze plankton abundance and water quality parameters before and after the placement of fish shelters in Nepa Waters, Banyuates District, Sampang Regency, Madura. Samples were collected at three observation stations before and after shelter installation and were then analyzed using statistical tests. Plankton identification revealed 5 classes: *Chlorophyceae*, *Cyanophyceae*, *Bacillariophyceae*, *Branchiopoda*, and *Oligohymenophora*. Plankton abundance before placement at stations 1,2, and 3 was 106, 420, and 427 ind/L, respectively, while total abundance increased after placement to 564, 758, and 489 ind/L. The diversity index (H') before placement ranged from 0.3-1.18 (low category) and increased afterward to 1.23-1.57 (moderate category). The uniformity index (E) ranged from 0.19-0.64 before placement and 0.62-0.68 after placement, both falling into the moderate category. The dominance index (D) was 1, indicating high dominance. Water quality parameters before and after shelter installation showed the following ranges: Temperature 30.1±0.058 - 31.7±0.12°C and 29.9-31.3°C; Transparency 35.3-100% and 43.53-100%; Light intensity 1 lux; pH 7.2±0.033 - 7.6±0.067 and 8.3±0.083 - 8.4±0.046; DO 8.1±0.033 - 8.6±0.033 mg/L and 5.4±0.285 - 7.1±0.088 mg/L; Salinity 35-37 ppt and 32-34 ppt; Nitrate 1.973±0.029 - 2.533±0.282 mg/L and 1.125±0.05 - 1.423±0.116 mg/L; Phosphate 0.228±0.006 - 0.557±0.092 mg/L and 1.05±0.014 - 1.16±0.047 mg/L.

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1. Introduction

Coastal waters are one of the ecosystems that play an important role in maintaining environmental balance and supporting the survival of various marine organisms. According to Nurholis and Mokodompit (2024) [23], this ecosystem provides a variety of important ecological functions so that it supports the life of aquatic organisms. Pasaribu and Ismail (2024) [28] explain that coastal areas function as habitats, nursery grounds, feeding grounds, as well as spawning grounds for various aquatic biota. In addition to having an ecological function, coastal areas are also a buffer for the lives of coastal communities, most of whom depend on fisheries activities and the use of other marine resources (Nurholis and Mokodompit, 2024) [23]. Thus, the sustainability of the coastal environment greatly determines the socio-economic stability of the people who live around it.

One of the biological components of water that is often used as an indicator of ecosystem conditions is plankton. Pankton consists of two large groups, namely phytoplankton and zooplankton, each of which has a different but interrelated role in the aquatic trophic network (Dewanti *et al*., 2018) [9]. Phytoplankton play a role as primary producers that carry out photosynthesis and produce oxygen, while zooplankton are primary consumers that channel energy to higher trophic levels such as fish (Junaidi *et al*., 2018; Bahri and Sarjan, 2025) [12] [5]. Due to its sensitivity nature to environmental changes, plankton abundance and diversity are often used as indicators of water quality conditions, both physical, chemical, and biological (Akbarurrasyid *et al*., 2024) [1].

Changes in water quality parameters such as temperature, salinity, pH, DO, brightness, and nutrients are known to greatly affect the dynamics of plankton communities, including their composition and species distribution (Sudinno *et al*., 2025) [32].

District, Sampang Regency, Madura, are one of the coastal areas that have considerable potential for fishery resources (Mufarrohah *et al*., 2023) [20]. This area has long been the main location for the activities of the fishing community, both in capture fisheries and various forms of aquaculture. However, like many other coastal areas in Indonesia, Nepa Waters face various ecological pressures. Based on the results of field surveys and interviews with local fishermen, some of the common problems include overfishing, destruction of natural habitats such as coral reefs and seagrass beds, and limited natural spawning areas for fish. In addition, the dynamics of water quality influenced by tidal factors, sedimentation, domestic activities, and changes in coastal land use also put pressure on the stability of aquatic ecosystems. These conditions ultimately impact plankton communities as primary producers that are highly sensitive to environmental changes (Nadillah *et al*., 2025) [21].

To overcome these problems, various conservation and coastal resource management efforts continue to be developed. One of the approaches that is starting to be widely applied is the installation of fish shelters or artificial fish houses. Fish shelters are artificial structures placed in waters with the main purpose of increasing the availability of habitat for fish, especially as shelters, spawning sites, and larval and juvenile breeding areas (Bahri *et al*., 2023; Ngii *et al*., 2023) [6] [22]. The presence of fish shelters is believed to increase the complexity of the habitat so that it is able to attract fish and other organisms to associate with it. Ecologically, the existence of such physical structures can alter certain habitat parameters, including current patterns, nutrient distribution, light intensity, and substrate conditions. These changes can indirectly affect water quality parameters and the dynamics of the plankton communities that live around them (Mahulette *et al*., 2025) [19].

Some previous studies have shown that the installation of fish shelters or other artificial structures can have a positive impact on aquatic ecosystems. Challouf *et al*. (2017) [7] reported that the existence of artificial structures can increase the brightness of water due to reduced turbidity and trigger an increase in dissolved oxygen through increased photosynthetic activity of phytoplankton. In addition, artificial structures can also alter current circulation patterns so that they can potentially affect the distribution of nutrients such as nitrates and phosphates, which are important factors in the growth of phytoplankton. These ecological changes can ultimately affect the composition of plankton communities, both in terms of abundance and diversity (Maherezky *et al*., 2023) [18].

The application of fish shelters also has strong relevance to the Sustainable Development Goals (SDGs). The construction of fish shelters directly supports the achievement of SDG 14: Life Below Water, especially in efforts to conserve marine ecosystems and use fishery resources in a sustainable manner. In addition, this innovation is in line with the concept of the blue economy, which emphasizes the economic growth of coastal communities through environmentally friendly and sustainable management of marine resources. By increasing habitat availability and fisheries productivity without causing ecological damage, fish shelters are one of the technologies that have the potential to be applied in coastal area management.

Based on this background, research on changes in plankton abundance and diversity, as well as water quality parameters before and after the installation of fish shelters in Nepa Waters, is very important to be carried out. Through this study, it can be known how the plankton community responds to environmental changes produced by the existence of fish shelters, as well as how these changes are related to fluctuations in water quality parameters such as temperature, pH, salinity, DO, brightness, light intensity, nitrates, and phosphates. The information obtained not only provides an overview of the ecological conditions of Nepa Waters, but also becomes a scientific basis for assessing the effectiveness of fish shelters as a means of conservation and increasing aquatic productivity.

The results of this study are expected to be a reference in the planning and management of coastal resources in Madura, especially in Sampang Regency. In addition to making a scientific contribution to the development of sustainable coastal environmental management strategies, this research also has an applicative impact to support the welfare of fishing communities that depend on the sustainability of fishery resources. Thus, this research not only provides academic value but also practical benefits in an effort to support environmentally sound fisheries and marine development.

2. Materials and Methods

2.1. Time and Place

The research was carried out in August-November 2025, including the preparation stage, location survey, sampling, laboratory analysis, and report preparation. Sampling was carried out in Nepa Waters, Banyuates District, Sampang Regency, Madura. The laboratory analysis was carried out at the Marine Fisheries Laboratory, Faculty of Agriculture, Trunojoyo University of Madura. The location of the research can be seen in Fig 1.

Fig 1: Research location

The location determination technique in this study uses *the purposive sampling method*. The research location is divided into 3 stations perpendicular to the coastline, with the central point being at the *fish shelter location*. Each station is taken at 2 points vertically, namely the surface and the bottom of the water. The determination of the location point is carried out using GPS Maps, and the station location coordinate points are recorded as presented in Table 1.

Table 1: Coordinates of the location of the research station

Station	Location	Coordinates	Depth (meters)	
			Surface	Basis
1	*Fish shelter*	6°53′24"S 113°13′16"E	0	1,73
2	150 meters towards the sea	6°53′20"S 113°13′18"E	0	1,80
3	150 meters towards the beach	6°53′29"S 113°13′14"E	0	1,38

2. Tools and Materials

The tools used include a 10-micron plankton net, *a water sampler* (WILCO), a DO meter (Lutron WA-2017SD), a pH meter (ATAGO 4320), a refractometer (ATC), a lux meter (LX-1010B), *a secchi disk*, GPS maps (GARMIN 62s), a binocular microscope (OLYMPUS DP21), *a sedgwick rafter*, and a UV-Vis spectrophotometer (SHIMADZU). The research materials include seawater samples, lugol solution (C_6H_5OH), as well as analytical chemicals such as sodium chloride (NaCl), brusin ($C_{23}H_{26}N_2O_4$), sulfanilac acid ($C_6H_7NO_3S$), hydrochloric acid (HCl), potassium nitrate (KNO_3), sulfuric acid (H_2SO_4), phenolphthalein ($C_{20}H_{14}O_4$), potassium sodium tartrate ($K(SBO)C_4H_4O_6.1*2H_2O$), ammonium molybdate ($C_{10}H_{14}N_2O_8*2Na*2H_2O$), ascorbic acid ($C_6H_8O_6$), potassium dihydrogen phosphate (KH_2PO_4), and aquades.

3. Research Methods

The study used a quantitative descriptive method by collecting primary data in the form of plankton and water quality parameters. Water quality data collection was carried out *in situ* at the research site, while the analysis of water quality parameters that could not be measured at the site was carried out *ex-situ* in the laboratory. Analysis of plankton data, including type and abundance identification, was also carried out in the laboratory using microscopes and plankton identification tools. The data obtained was then processed statistically to determine the condition of water quality and plankton diversity, and the results were compared with quality benchmarks and relevant previous research.

4. Plankton Sampling

Plankton sampling refers to the research of Indriyawati *et al*. (2023), which was carried out by taking 50 liters of water at each depth with a *water sampler* and filtering it using a 10-micron plankton net. The sieve results were then stored in a sample bottle and fixed using 2-3 drops of Lugol solution. It is then stored in *a cool box* for further analysis in the laboratory.

5. Water Quality Parameter Measurement

The parameters measured *in situ* include temperature and DO measured using a DO meter, pH using a pH meter, salinity using a refractometer, brightness using *a secchi disk*, and light intensity using a lux meter. The nutrient parameters, i.e., nitrates and phosphates, were analyzed *ex-situ* in the laboratory. Nitrate levels were measured using the brusin sulfate method (SNI M-49-1990-03), while phosphate was measured using the ascorbic acid method (SNI 06-6989.31-2005); both parameters were measured using a spectrophotometer. The data from water quality measurement is then compared with the quality standard reference of Government Regulation No. 22 of 2021.

7. Plankton Identification

The identification of plankton results was carried out in the laboratory, referring to the research of Paiki *et al*. (2019) [27]. Plankton observations were carried out using a Sedgwick Rafter with a volume of 1 ml. The sample was observed under a binocular microscope with a magnification of 40x using the sweep method, which is to chop all types of plankton present in the volume of water. Plankton species identification refers to identification manuals (Suthers and Rissik, 2009;

Kurniawan *et al*., 2023; and Padang, 2023) [34] [14] [24]. Plankton abundance is calculated based on the number of individuals per liter.

3. Data Analysis

Plankton Abundance Index (N)

The abundance value (N) is used to determine the amount of plankton in each volume (ind/L). The analysis of plankton abundance was calculated using the APHA formula (2005) [2].

$$\mathrm{N} = \frac{1}{V} \times \frac{Vt}{Vs} \times n$$

Information:
N = Plankton abundance (ind/L)
N = Number of individuals dismembered
V = Volume of filtered water (50 Liters)
Vt = Sample volume (45 ml)
Vs = Sample volume in SRC (1 ml)

Diversity Index (H')

The diversity index value (H') is used to determine the level of plankton diversity in a population. The analysis of the plankton diversity index was calculated based on the Shannon-Wiener index equation formula in Sukardi and Arisandi (2020) [33].

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

Information:
H' = Diversity index
N = The total number of individuals of all types
Ni = Number of types of individuals i

The range of diversity index (H') values can be classified as follows:
0 < H' < 1 (Low Diversity)
1 < H' < 3 (Moderate Diversity)
H' > 3 (High Diversity)

Uniformity Index (E)

The uniformity index value (E) is used to indicate the amount of similarity between plankton types in a population. The analysis of the plankton uniformity index was calculated based on Evennes in Sukardi and Arisandi (2020) [33].

$$\mathrm{E} = \frac{\mathrm{H}'}{\mathrm{H\ max}}$$

Information:
E: Uniformity index
H': Diversity index
H max: Ln of S (maximum diversity index)
S: Number of plankton species found

The range of uniformity index values (E) can be classified as follows:
0 < E < 0.5 (Low uniformity)
0.5 ≤ E ≤ 0.75 (Medium uniformity)
0.75 < E ≤ 1 (High uniformity)

Dominance Index (D)

The dominance index (D) is used to see whether or not there is a degree of dominance by a particular species in the plankton community. The analysis of the plankton dominance index was calculated based on Simpson in Sukardi and Arisandi (2020) [33].

$$D = \sum \left(\frac{ni}{N}\right)^2$$

Information:
D: Dominance Index
Ni: Number of individuals of the i-i species
N: Total number of plankton per sampling point

The range of values of the dominance index (D) can be classified as follows:
0 < E ≤ 0.5 (Low dominance)
0.5 ≤ E ≤ 0.75 (Medium dominance)
0.75 < E ≤ 1 (High dominance)

Hypothesis Test

The statistical test in this study aims to determine whether or not there is a significant difference in the abundance of plankton types and water quality parameters in the conditions between before and after the placement of *fish shelters* in Nepa Waters, Sampang Regency, Madura. Data analysis is carried out using the help of Microsoft Excel and SPSS software. Normality tests were carried out to determine the distribution of data. If the data is normally distributed, the hypothesis test is continued using the *Paired Sample T-Test*; if the data is not distributed normally, the non-parametric *Wilcoxon Signed Rank Test is used*. The results of the hypothesis test were determined based on the significance value (p-value) with a confidence level of 95% ($\alpha = 0.05$).
H0: There is no significant difference.
H1: There is a significant difference.

3. Results and Language

3.1. Identification and Abundance of Plankton Species

The results of the identification and analysis of plankton abundance in the waters of the study site showed that there was a clear difference in community structure between the conditions before and after the placement of *the fish shelter*. Before installation, plankton communities were dominated by several phytoplankton species such as *Chlorella sp.*, *Chaetoceros gracilis*, and *Asterionella formosa*, with abundance that tended to vary between stations. After the installation of *fish* shelters, there was an increase in abundance in several dominant species such as *Chaetoceros gracilis*, *Chlorella sp.*, and *Oscillatoria sp*. This increase indicates an improvement in habitat structure that contributes to an increase in primary productivity and the stability of plankton communities. These changes in species composition and abundance provide an idea of the ecological response of the waters to the existence of *fish shelters*. The results of the identification of species and their abundance at each station are presented in Tables 2 and 3.

Table 2: Plankton abundance before *the placement of fish shelters*

Class	Species	Station 1		Station 2		Station 3	
		P	D	P	D	P	D
Phytoplankton							
Stuart O'Neill	*Chlorella sp.*	34	42	0	0	3	71
	Tetraselmis sp.	8	5	0	0	1	18
Cyanophyceae	*Oscillatoria sp.*	0	1	4	3	0	1
	Microcystis sp.	1	0	0	0	2	5
Bacillariophyceae	*Synendra sp.*	0	0	0	0	0	2
	Monolight Climacosphonia	0	0	0	0	0	1
	Guinardia flaccida	0	0	0	0	0	0
	Eucampia sp.	0	0	0	0	0	1
	Leptocylindrus sp.	0	0	0	0	0	0
	Nitzschia reversa	0	0	0	1	0	2
	Navicula sp.	8	6	0	0	6	5
	Chaetoceros gracilis	0	0	161	155	177	132
	Asterionella formosa	0	0	81	15	0	0
	Cyclotella sp.	0	0	0	0	0	0
Total:		51	54	246	174	189	238
Zooplankton							
Branchiopoda	*Dhapnia sp.*	1	0	0	0	0	0
Oligohymenophore	*Paramecium caudatum*	0	0	0	0	0	0
Total:		1	0	0	0	0	0
Total plankton abundance:		52	54	246	174	189	238

Table 3: Plankton abundance after *fish shelter placement*

Class	Species	Station 1		Station 2		Station 3	
		P	D	P	D	P	D
Phytoplankton							
Stuart O'Neill	*Chlorella sp.*	49	94	72	165	116	84
	Tetraselmis sp.	12	14	8	4	0	0
Cyanophyceae	*Oscillatoria sp.*	15	6	19	29	17	6
	Microcystis sp.	49	22	6	23	28	23
Bacillariophyceae	*Synendra sp.*	12	5	13	12	8	0
	Monolight Climacosphonia	1	1	0	0	1	0
	Guinardia flaccida	2	0	0	0	0	0
	Eucampia sp.	0	0	0	0	0	0
	Leptocylindrus sp.	0	1	1	3	1	2
	Nitzschia reversa	0	0	0	4	0	0
	Navicula sp.	4	5	7	17	12	7
	Chaetoceros gracilis	153	107	168	172	88	93
	Asterionella formosa	0	0	0	0	0	0
	Cyclotella sp.	0	0	0	0	1	0
Total:		297	255	294	429	272	215
Zooplankton							
Branchiopoda	*Dhapnia sp.*	2	0	0	2	2	0
Oligohymenophore	*Paramecium caudatum*	10	0	9	24	0	0
Total:		12	0	9	26	2	0
Total plankton abundance:		309	255	303	455	274	215

Changes in community structure and plankton abundance after fish shelter placement indicate a clear ecological response to habitat quality improvement. Before the installation of the fish shelter, the total abundance of plankton was recorded at 106 ind/L at station 1, 420 ind/L at station 2, and 427 ind/L at station 3. After installation, the abundance increased significantly to 564 ind/L at station 1, 758 ind/L at station 2, and 489 ind/L at station 3. This increase is indicated by an increase in phytoplankton from the *Bacillariophyceae* and *Chlorophyceae* groups, where diatoms such as *Chaetoceros gracilis*, *Navicula* sp., and *Synendra* sp. become more abundant. The pattern is consistent with the findings of Kaur and Khalid (2020) [13], who reported that diatoms thrive better in waters that experience increased stability and nutrients after changes in the physical structure of the environment.

In addition, *Cyanophyceae* such as *Oscillatoria* sp. and *Mycrocystis* sp. There is also an increase in abundance after the installation of the fish shelter. This condition indicates the enrichment of nutrients, especially nitrates and phosphates, which can occur in locations with high biota activity and accumulation of organic matter. This is in line with the explanation of Paerl and Otten (2023) [25] that Cyanobacteria are very responsive to increased nutrient load and are able to dominate in environments that experience changes in the structure of microhabitats.

Fish shelters function as artificial structures that are able to slow down microcurrents, increase nutrient retention, and provide a surface for the growth of organisms, thus supporting increased primary productivity. Lima *et al*. (2019)

[16] show that artificial reefs and other artificial structures can increase the abundance of plankton and fish through changes in the physical conditions of the waters. This finding is reinforced by Dempster and Taquet (2004) [8], who stated that structures such as fish aggregating devices not only attract fish, but also increase the concentration of planktonic organisms through habitat modification.

3.2. Diversity Index (H')

The diversity index (H') is used to describe the stability of plankton communities and the distribution rate of species in a watershed. This index value provides information about whether the plankton community is in a stable, depressed, or dominated condition by one or more specific species. The analysis of the diversity index (H') in this study was carried out to compare the conditions of plankton communities before and after the placement of *fish shelters* at each observation station. A comparison of the values of the diversity index is shown in the graph in Fig 2. To facilitate the interpretation of changes in the structure of plankton communities.

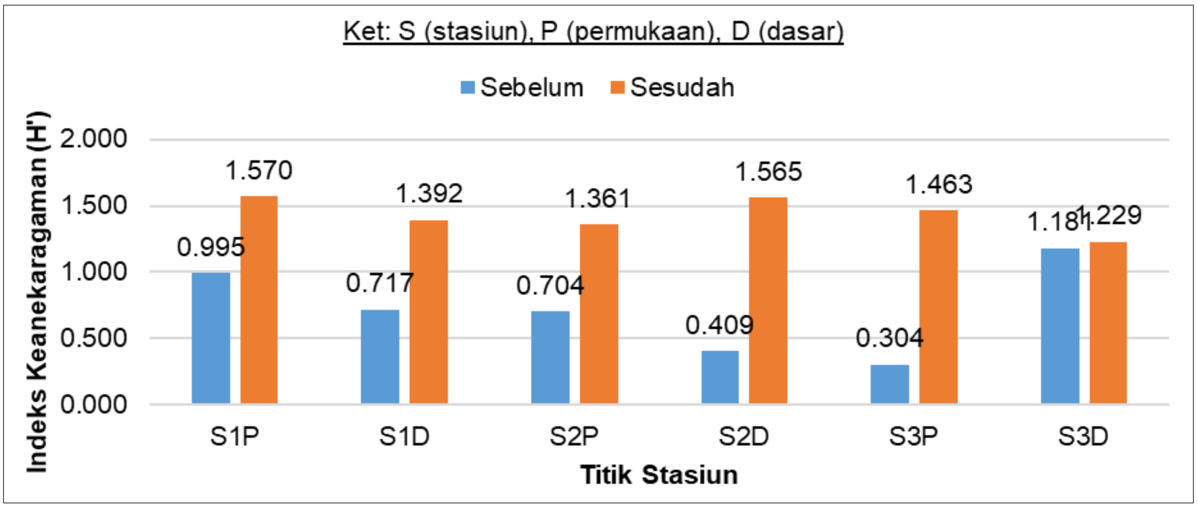

Fig 2: Diversity index (H') graph

The results of the analysis showed that the value of the diversity index (H') of plankton before the installation of *the fish shelter* was in the range of 0.3-1.18, while after the installation of *the fish shelter* increased to 1.22-1.56 at all stations on the surface and bottom of the water. The increase in this index value indicates a change in the community structure towards more stable and diverse conditions. Before the installation of *fish shelters* at some stations showed low H' values, especially at station 3, which reflected the dominance of certain species, especially *the Chaetoceros gracilis species*. After the installation of *the fish shelter*, the H' value increased significantly, especially at stations 1 and 2, indicating a more balanced community.

The increase can be attributed to the function of the fish shelter as an artificial structure that supports habitat authenticity and improves ecological conditions. This structure is able to slow down currents, increase nutrient retention, and provide a surface for a variety of microorganisms, thus increasing the chances of more plankton species being present. This fact is in accordance with the findings of Lima *et al*. (2019) [16], who stated that artificial reefs or artificial habitats can increase the diversity of aquatic organisms through increasing the complexity of microhabitats. In addition, the higher value of the diversity index (H') after the installation of fish shelters is also consistent with the opinion of Reynolds (2006) [31] that the increase in the physical stability of the waters and the availability of nutrients will increase the diversity of phytoplankton as primary producers.

Overall, the increase in the diversity index (H') suggests that the installation of *fish shelters* contributes to the increased stability of plankton communities in Nepa Waters. A more diverse community reflects healthier and more productive water conditions, thereby supporting ecosystem sustainability and increasing the carrying capacity of other aquatic biota, including target fish.

3.3. Uniformity Index (E)

The uniformity index (E) is used to assess the level of equal distribution of abundance between species in plankton communities at each research station. A high uniformity index value (E) indicates that species are relatively evenly distributed in the absence of excessive dominance, while a low uniformity index value (E) indicates community imbalance and the presence of predominantly one species. This analysis provides an overview of the stability of plankton communities before and after *the placement of fish shelters*, and the comparison of uniformity index values is shown in the graph in Fig 3.

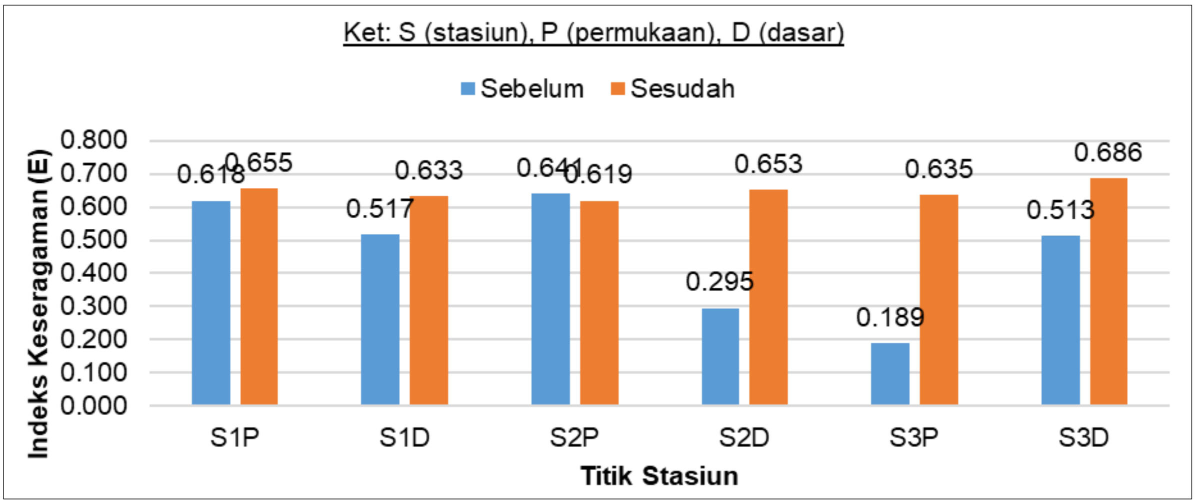

Fig 3: Uniformity index graph (E)

The results of the uniformity index (E) calculation showed that before the installation *of the fish shelter*, the uniformity index value (E) was in the range of 0.18-0.64, with the lowest value at station 3 points of the water surface, indicating the dominance of certain species, especially *Chaetoceros gracilis*. Low uniformity values describe unstable communities and indicate dependence on dominant species. After the installation of *the fish shelter*, the uniformity index value (E) increased and was in the range of 0.61-0.68 across stations and treatments, indicating a more balanced community and no longer dominated by a single species.

This increase in uniformity value shows that fish shelters play a role in improving the structure of plankton communities. Fish shelters are able to create more heterogeneous and stable physical conditions that support a more even distribution of species. This is in line with the research of Lima *et al*. (2019) [16], who stated that the existence of artificial structures can increase the stability and distribution of organisms due to changes in microcurrents and habitat heterogeneity. Reynold (2006) [31] also emphasized that more stable physical conditions of waters can increase the equitable distribution of phytoplankton communities due to reduced environmental pressures that usually trigger dominance by certain species.

Overall, the increase in the uniformity index (E) value after the installation of *the fish shelter* indicates that the plankton community in Nepa Waters has become more balanced and stable. Higher uniformity reflects more uniform ecological interactions between species and is an indicator of improved quality of aquatic ecosystems, which will ultimately support the sustainability of other biota communities.

3.4. Dominance Index (D)

The dominance index (D) is used to measure the level of mastery of one or more species in a plankton community. A high dominance value indicates that a community is dominated by a few species, while a low dominance value reflects a more balanced community. This analysis is important to understand whether habitat changes due to *fish shelter* placement have an influence on the dominance tendencies of certain species. The dominance index graph (D) is presented in Fig 4. To clarify the difference in dominance patterns before and after the installation of *fish shelters*.

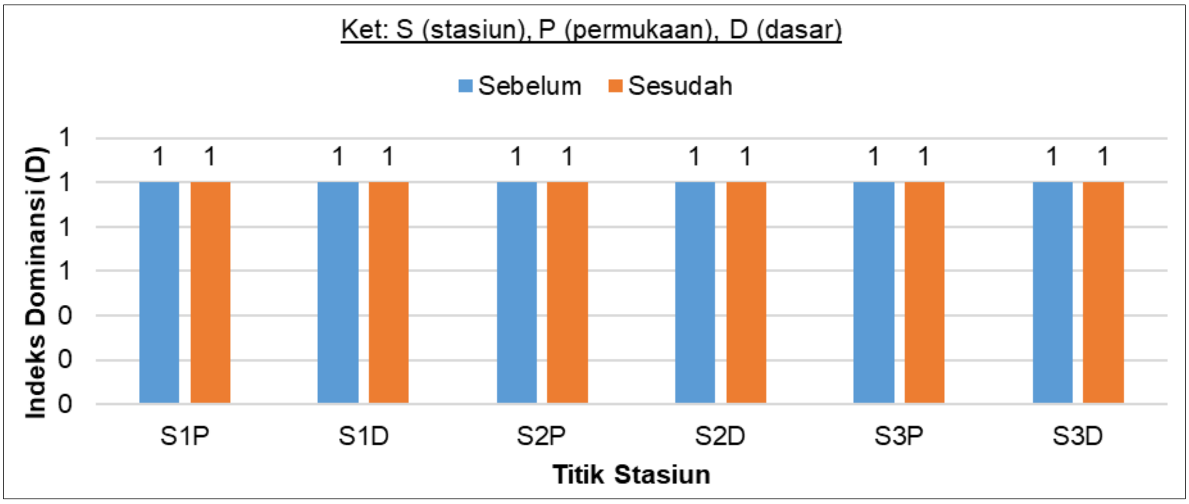

Fig 4: Dominance index chart (D)

Based on the calculation results, the dominance index value (D) before the *placement of the fish shelter* was 1 in all stations and treatments, which indicates that the plankton community still shows strong dominance by certain species. This condition is seen especially in the abundance of diatoms such as *Chaetoceros gracilis*, which dominates at stations 2 and 3. However, after the installation of *the fish shelter*, the dominance value remained in the range of 1, but with a change in the composition of the dominant species. Although the dominance index value (D) appears to be numerically stable, communities show a more varied distribution of species due to the increasing number of species present in the community.

The phenomenon of stable dominance values but with changing species composition can be explained through the dynamics of competition and plankton adaptation after habitat modification. The addition of fish shelters can affect the distribution of light, water flow, and the availability of nutrients, which ultimately creates new conditions for some plankton species to thrive. According to Ghobrial and Hassan (2022) [10], the dominance of species in aquatic ecosystems is greatly influenced by changes in the microenvironment that can benefit certain species that have faster adaptation capabilities than other species.

In addition, a change in dominance can also occur due to the emergence of new competition between phytoplankton and zooplankton. The study of Liu *et al*. (2021) [17] suggests that changes in environmental structures, such as new currents and substrates, can accelerate the shift in dominance due to changes in biological interactions between species. This is in accordance with the pattern in Nepa Waters, where after the installation of fish shelters, the dominant species do not only come from one group, but are spread across several classes, such as *Bacillariophyceae*, *Chlorophyceae*, and *Cyanophyceae*.

Overall, the dominance index value (D) remains high, indicating that the plankton community in Nepa Waters remains in a condition of species dominance, but the type of species that dominates has changed after the installation of *fish shelters*. This indicates that *fish shelters* not only affect abundance and diversity but also modify the structure of competition within plankton communities.

3.5. Aquatic Water Quality Parameters

Water quality analysis in this study was carried out to determine the physical and chemical conditions of the waters before and after the placement of *the fish shelter*, which included temperature, brightness, light intensity, pH, DO, and salinity parameters. These parameters play an important role in influencing the dynamics of plankton communities and the stability of aquatic ecosystems. This understanding of water quality value variations provides an overview of changes in environmental conditions that occur after the installation of *fish shelters*, so that it can support interpretations of changes in plankton abundance and diversity. The results of the measurement of the physical and chemical parameters of the waters are presented in Tables 4 and 5.

Table 4: Results of water quality measurements, water physics, and chemical parameters

Parameters	**Water Quality Results**						**Quality Standards**
	Before			**After**			
	St 1	**St 2**	**St 3**	**St 1**	**St 2**	**St 3**	
Physics							
Temperature (°C)	31,7±0.120	30,1±0.058	30,2±0.058	29,9	31±0.067	31,3	28 – 30
Brightness (%)	100	35,3	100	43,53	100	100	>5
Light Intensity (lux)	1	1	1	1	1	1	-
Chemistry							
Ph	7,2±0.033	7,6±0.067	7,2±0.067	8,4±0.046	8,3±0.083	8,4±0.035	7 – 8,5
DO (mg/L)	8,1±0.033	8,6±0.033	8,2±0.033	5,4±0.285	7,1±0.088	6,9±0.291	>5

The results of the measurement of the physical and chemical parameters of the waters after the installation of the fish shelter showed a close relationship with the increasing dynamics of the plankton community. Aquatic temperatures in the range of 29.9-31.7°C are the optimal range for phytoplankton growth in tropical areas. This condition is in line with the findings of Rajesh *et al*. (2021) [30], who stated that temperatures of 28-30°C support photosynthetic activity and phytoplankton cell division in warm waters. A small decrease in temperature after the installation of the fish shelter indicates a small shading effect that, according to Walter *et al*. (2020) [35], can improve the stability of the plankton community through the reduction of thermal fluctuations.

The brightness of the waters has increased significantly, where all stations reaching 100% after the installation of the shelter. This high availability of light greatly supports the process of photosynthesis, especially for the *Chlorophyceae* and diatoms group. The increase in brightness is in line with the view of Reynolds (2006) [31], who states that light is the most important limiting factor in increasing primary productivity in waters. This may explain the significant increase in plankton abundance after the installation of fish shelters, when light penetration is more optimal.

The pH value that increased from 7.2-7.6 to 8.3-8.4 after the installation of the fish shelter reflected an increase in the rate of photosynthesis. The absorption of CO2 by phytoplankton will increase the alkalinity of the waters, as explained by Uppal *et al*. (2022), that the increase in pH is directly correlated with the increase in phytoplankton photosynthetic activity. Slightly decreased DO values at some points, such as at Station 1 from 8.1 mg/L to 5.4 mg/L, are still in the safe category, and according to Lalli and Parsons (2021) [15], DO decreases often occur in high-productivity waters due to increased respiration of microorganisms.

Salinity that decreases from 35-37 ppt to 32-34 ppt also has important implications for the structure of plankton communities. According to Paerl *et al*. (2018) [26], salinity changes, even if small, can shift the dominance of certain plankton groups, especially *Cyanophyceae*, which are highly tolerant of salinity variability. This pattern is consistent with the discovery of an increase in *Oscillatoria* and *Microcystis* species after the installation of fish shelters.

Table 5: Results of water quality measurement of nitrate and phosphate parameters

Treatment	Station		Parameters	
			Nitrate (mg/L)	Phosphate (mg/L)
Before	1	Surface	2,322±0.095	0.233±0.005
		Basis	2,533±0.282	0.274±0.003
	2	Surface	1,973±0.029	0.557±0.092
		Basis	2,119±0.042	0.493±0.094
	3	Surface	2,007±0.054	0.228±0.006
		Basis	2,177±0.017	0.258±0.014
After	1	Surface	1.125±0.05	1.05±0.014
		Basis	1,278±0.071	1.16±0.047
	2	Surface	1,286±0.029	1,058±0.028
		Basis	1,390±0.067	1.11±0.025
	3	Surface	1,211±0.112	1,066±0.008
		Basis	1.423±0.116	1,122±0.042
Quality Standards			**0,06**	**0,015**

The results of the nitrate value showed a significant decrease from 1.97-2.53 mg/L to 1.12-1.42 mg/L after the installation of the fish shelter. This decline illustrates the increased nitrate consumption by phytoplankton. Zhang *et al*. (2020) [37] explain that a rapid decline in nitrate concentrations is usually an indicator of accelerated primary production in eutrophic waters, especially by the class *Bacillariophyceae*. This corresponds to the increasing abundance of diatoms such as *Chaetoceros gracilis* and *Navicula* sp. throughout the station. In contrast, phosphate levels increased significantly from 0.22-0.55 mg/L to 1.05-1.16 mg/L after the installation of fish shelters. Phosphorus tends to increase in areas with artificial structures due to the accumulation of organic matter and the release of phosphorus from trapped sediments. This phenomenon is explained by Wu *et al*. (2019) [36], who stated that artificial structures in waters can increase phosphate due to a decrease in the flow rate and an increase in the remineralization process. This higher phosphate then plays an important role in increasing phytoplankton abundance, as phosphate is one of the main limiting nutrients in tropical plankton ecosystems.

The pattern of differences in dynamics between nitrates and phosphates reflects increased biological activity around fish shelters. A decrease in nitrate indicates a high consumption of phytoplankton, while an increase in phosphate indicates a contribution from the process of decomposition, sedimentation, and greater accumulation of nutrients. With this in mind, these two parameters suggest that the installation of fish shelters creates zones with more intense and productive biogeochemical activities.

Hypothesis Test

The results of the hypothesis test on the difference in conditions before and after the placement of fish shelters showed that there was a significant variation in responses to several aquatic ecological parameters. The hypothesis test was carried out using a significance value (sig), where the criterion used was H0 rejected if the value was sig<0.05, which means that there is a real difference between treatments. On the other hand, H0 is accepted if the value of sig>0.05 indicates that there is no significant difference.

In the plankton abundance parameter, a significance value of 0.034 indicates that there is a significant difference between the conditions before and after the installation of fish shelters. This is in line with findings in abundance data that show a large increase in all stations, so that fish shelters have been shown to have a significant ecological influence on the increase in plankton abundance. These changes reflect increased physical stability of the waters, increased light penetration, as well as the accumulation of nutrients that support phytoplankton growth.

The test results on the nitrate parameter showed a sig value of 0.000, so that H0 was rejected and there was a significant difference before and after the installation of the fish shelter. The decrease in nitrates after shelter installation showed an increase in utilization by phytoplankton, in line with an increase in total plankton abundance. This indicates that fish shelters play a role in supporting the process of nutrient absorption by primary producers.

Similarly, the phosphate parameter shows a sig value of 0.000, which signifies a significant difference. Increased phosphate after shelter installation can be caused by the process of remineralization of organic matter and the release of phosphate from sediment in areas where the current is weakened due to the presence of artificial structures. Phosphate supports the growth of certain phytoplankton, especially in diatoms and *Cyanophyceae*.

In contrast, some parameters do not show a difference in nyhata. The temperature parameter is a sig value of 0.95, the brightness of the sig value is 0.665, the light intensity is a sig value of 1, the DO is a sig value of 0.052, and the salinity of the sig value of 0.102, each of which has a sig>0.05 value so that H0 is accepted. This suggests that the changes that occur in the physical and chemical parameters are not statistically strong enough to be categorized as significant. Although brightness values increased on descriptive observations, hypothesis tests showed that variation between treatments was still within natural limits that did not show statistically drastic changes. Similarly, the DO and salinity parameters are in an ecologically stable condition, although they experience slight fluctuations.

However, the pH parameter shows a sig value of 0.029, so there is a significant difference. The increase in pH at all stations after the installation of the fish shelter reflects the increased photosynthetic activity of phytoplankton. This supports the results of plankton abundance tests, as phytoplankton's biological activity directly affects CO2 uptake and causes an increase in pH.

Overall, the results of the hypothesis test show that the installation of fish shelters has a significant influence on biological variables that are directly related to primary productivity, namely the abundance of plankton, nitrates, phosphates, and pH. While other physical and chemical parameters of the waters show relatively high stability and do not differ significantly. This shows that ecological changes that occur are more predominantly influenced by biological responses to habitat modification than by changes in the physical conditions of the bottom of the waters.

4. Conclusion

1. The results of plankton identification in Nepa Waters found 16 species of plankton belonging to five classes, namely *Chlorophyceae*, *Cyanophyceae*, *Bacillariophyceae*, *Branchiopoda*, and *Oligohymenophora*. After the placement of *the fish shelter*, there was a marked increase in plankton abundance, from the range of 52-246 ind/L to 215-455 ind/L with a significant difference of 0.034. The diversity index (H') increased from 0.3038-1.181 to 1.2285-1.5696, and the uniformity index (E) also rose from 0.1888-0.6412 to 0.6194-0.6856, while the dominance (D) remained stable at a value of 1. These results show that *fish shelters* have a positive influence on increasing the diversity and structure of plankton communities in Nepa Waters.
2. The condition of the water quality parameters showed a change after the placement of *the fish shelter*, with the temperature decreasing from 31.7±0.120-30.1±0.058°C to 29.9-31±0.067°C, the brightness increased from 35.3-100% to 43.53-100%, and the light intensity remained at 1 lux. The pH value increased from 7.2±0.033-7.6±0.067 to 8.3±0.083-8.4±0.046, while the DO decreased from 8.1±0.033-8.6±0.033 mg/L to 5.4±0.285-7.1±0.088 mg/L, and the salinity changed from 35-37 ppt to 32-34 ppt. Nitrate concentrations decreased from 1.973±0.029-2.533±0.282 mg/L to 1.125±0.05-1.423±0.116 mg/L, while phosphate increased from 0.228±0.006-0.557±0.092 mg/L to 1.05±0.014-1.16±0.047 mg/L. Significant changes in pH, nitrates, and phosphates showed that fish *shelter placement* had a significant influence on water quality dynamics in Nepa Waters.
3. The results of the analysis showed that changes in water quality parameters after *fish shelter placement* had a significant relationship with plankton diversity, where increased pH values, salinity changes, and decreased nitrate went hand in hand with increased diversity, uniformity, and abundance of plankton. Parameters that experience significant differences, namely pH, nitrate, and phosphate, are the most influential factors on the structure of plankton communities, so that the placement of *fish shelters* not only changes the characteristics of the waters, but can also encourage an increase in the diversity of plankton types in Nepa Waters.

5. Suggestion

Further research is suggested to extend the monitoring period so that seasonal changes in water quality and plankton diversity can be observed more accurately, add water quality parameters such as ammonia, BOD, COD, or chlorophyll-a to expand the scope of analysis, and increase the number of stations and sampling depths to obtain a more detailed spatial picture. In addition, the surrounding community is expected to help maintain the existence of *fish shelters* by not carrying out activities that can damage the structure and quality of the waters, as well as supporting efforts to preserve the ecosystem through pollution reduction and environmentally friendly fishing practices, so that the sustainability of ecological conditions and biodiversity in the Nepa Waters can continue to be maintained.

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