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Community Structure, Abundance and Ecological Index of Phytoplankton in Jembrana Coastal Waters, Bali

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Abstract: Phytoplankton is an important component in aquatic ecosystems. Apart from producing oxygen, phytoplankton also act as primary producers in the food chain. Bali Sardinella (*Lemuru*) is an important fishery commodity in the Bali Strait, which is known to eat plankton (Plankton Feeder), so its existence depends on the distribution of plankton. This descriptive research aims to determine the community structure, abundance and ecological index of phytoplankton in the coastal waters of Jembrana Regency. Sampling was conducted in July 2023 at five observation stations in the coastal waters of Jembrana Regency (Pengambengan Beach, Perancak Beach and Delod Berawah Beach). Around 250 litres of seawater was filtered by a plankton net measuring 35 μm. The filtered samples collected in a 100 ml collecting bottle were then transferred to a 120 ml sample bottle and preserved in 4% formalin. The samples obtained were taken to the laboratory for observation under a microscope. This research shows that 66 types of phytoplankton were found to belong to 5 classes in the waters of Jembrana, Bali. The Bacillariophyceae class were found with the highest number of species (44 species), followed by the Dinophyceae (19 species), Chlorophyceae (1 species), Cryptophyceae (1 species), and Cyanophyceae (1 species). Based on the results of calculating phytoplankton abundance, various abundance values were obtained at each observation station. Station 2 has the highest abundance of phytoplankton with 297 individuals/l followed by Station 1 (221 individuals/l), Station 4 (130 individuals/l), Station 3 (127 individuals/l), and Station 5 (36 individuals/l). The species Diversity Index (H') ranges from 2.61 - 2.83, the Dominance Index (C) ranges from 0.07 - 0.13, and the Evenness Index (e) ranges from 0.72 - 0.95. The ecological index value shows that the phytoplankton community in Jembrana coastal waters included in the moderate diversity category is not dominant and evenly distributed. The ecological index value shows that the water quality is categorized as moderately polluted.

Keywords: Abundance; Community Structure; Ecological Index; Jembrana; Phytoplankton.

Introduction

The coastal waters of Jembrana Regency are one of the coastal areas located in Bali Province. Jembrana Regency has an area of 604.24 km^2 with advantages in the agricultural and fisheries sectors. The main activities of the Jembrana people are farming, cultivation and fishing. An increase in community activities will, of course, be accompanied by an increase in the volume of anthropogenic waste produced, which has the potential to enter the water [1,2].

The coast of Jembrana Regency has an estuary area, which is the outfall of several rivers. The flow of river water, which is rich in nutrients, will eventually enter the sea. Organic waste in water will decompose and increase the concentration of Nitrogen (N) and Phosphorus (P) in the water. The nutrients N and P are the main factors influencing phytoplankton growth [1]. Water quality will affect the biota that lives in it, especially phytoplankton [3].

Phytoplankton play an important role in aquatic ecosystems. Phytoplankton act as primary producers that provide food for zooplankton and larvae of fish, shrimp and shellfish. Several types of phytoplankton have also been used as natural food in the fish, shrimp and pearl shell farming sectors [4,5]. Bali Sardinella (*Lemuru*) is an important fishery commodity in the Bali Strait which is known to eat plankton (Plankton Feeder), so its existence depends on the distribution of phytoplankton [6,7].

Apart from positively impacting aquatic ecosystems, phytoplankton also have a negative impact if a population explosion occurs. Several phytoplankton species are known to be dangerous for aquatic biota and humans [8,9]. Seeing the potential and effects caused by phytoplankton in marine ecosystems, it is necessary to research and determine the community structure, abundance, and ecological index of phytoplankton in the coastal waters of Jembrana Regency.

Research Methods

Time and Location of Research

Sampling was conducted in July 2023, located in the coastal waters of Jembrana Regency (Pengambengan Beach, Perancak Beach and Delod Berawah Beach). The sampling location is divided into five stations as shown in Figure 1.

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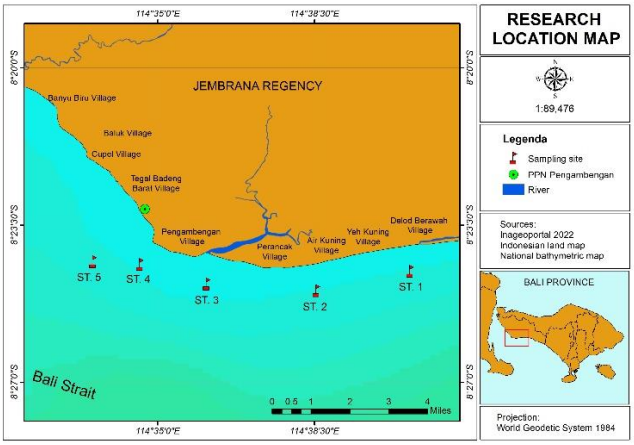

Figure 1. Research location

Sampling Method

Sampling was carried out by filtering 250 litres of seawater with a plankton net measuring 35 µm. The filtered samples collected in a 100 ml collecting bottle were then transferred to a 120 ml sample bottle and preserved in 4% formalin. The samples obtained were taken to the laboratory for observation under a microscope.

Plankton identification and counting

Sample observations in the laboratory were carried out using a binocular microscope by adding two drops (0.12 ml). Plankton samples observed under the microscope were identified using the plankton identification book in [10]; [11,12]. After the phytoplankton were identified, the number of each species of plankton found was then carried out by repeating five times.

Determination of Phytoplankton Abundance and Ecological Index

Calculating plankton abundance is to obtain information on the number of individual plankton in 1 litre of seawater. Abundance calculations are carried out based on the formula [13]:

$$N = n \; x \; \frac{Vr}{Vo} \; x \; \frac{1}{Vs}$$

Information:
N : Abundance of plankton (ind/L)
n : the number of plankton observed
Vr : Sample volume (ml)
Vo : Observed water volume (ml)
Vs : Volume of filtered water

The diversity index refers to the Shannon–Wiener Diversity Index [14].

$$H' = -\sum pi \ln pi$$

Information:
H' : Diversity Index
pi : ni/N
ni : Number of individuals of species-i
N : Total number of individuals

With the following criteria:
H'<1 : Low community stability
1<H'<3 : Moderate community stability
H'>3 : High community stability

Species Evenness Index (e) is calculated using the formula [13]:

$$e = H'/H_{maks} \quad ; H_{maks} = \ln S$$

Information:
e : Species Evenness Index
H' : Species Diversity Index
H'_{maks} : Maximum Diversity Index
S : Number of species

With the following criteria:
e > 0.6 : The level of evenness of taxa is even
0.4 < e < 0.6 : The level of abundance of taxa is quite evene
< 0.6 : The level of evenness of taxa is uneven

The plankton Dominance Index (C) is calculated using a formula [15]:

$$C = \sum (\frac{ni}{N})^2$$

Information:
C : Dominance Index
ni : Number of individuals of species-i
N : Total number of individuals

Results and Discussion

Based on the observations, 66 phytoplankton species belonged to 5 classes: Bacillariophyceae, Dinophyceae, Chlorophyceae, Cryptophyceae, and Cyanophyceae. Phytoplankton from the Bacillariophyceae class has the highest number of species (44 species), followed by the Dinophyceae class with 19 species, Chlorophyceae with one species, Cryptophyceae with one species, and Cyanophyceae with one species. The distribution of phytoplankton species found at each observation station is presented in Table 1.

The results obtained were relatively higher when compared with the results of other research in other locations in the coastal waters of Bali Island. Sixteen phytoplankton genera fall into two classes (Bacillariophyceae and Dhinophyceae) in the waters of Benoa Bay, with the highest composition being the Bacillariophyceae class [16]. The total abundance of individual phytoplankton ranged between 168.07 – 2,500, 59 cells/L, with an average value of 878.87 cells/L. Diversity index 0.31 – 1.47, species uniformity index 0.14 – 0.58, Dominance 0.31 – 0.89. The same thing was also reported by [17], who found 16 phytoplankton genera belonging to 3 classes (Bacillariophyceae, Cyanophyceae and Dinophyceae) in the waters around the harbour in Bali (Pengambengan, Benoa and Amed) with a diversity index of 1.22, uniformity index of 0.91, and a dominance index of 0.36.

Research conducted by [18] in the waters around Serangan Island found 22 genera from 3 classes (Bacillariophyceae, Cyanophyceae, and Dinophyceae) with abundances ranging from 1,239.73 ind/L – 7,664.65 ind/L. diversity index 0.2 – 0.98, aquatic environmental factors influencing phytoplankton abundance are pH, temperature, salinity, turbidity and phosphate. There is a strong relationship between the abundance of phytoplankton and zooplankton. Phytoplankton diversity is not closely related to zooplankton diversity[18].

Based on the results of this research, the phytoplankton class with the highest number of species is Bacillariophyceae (Figure 2). Bacillariophyceae, or Diatoms, is commonly found in fresh and marine waters. Several studies conducted in the waters around Bali also found this class to be the dominant species. The distribution and abundance of diatoms are usually influenced by the nutrient content in the water [19]. The nitrogen elements limiting factors for phytoplankton growth are phosphate, nitrate and silica [20]. The ratio of nitrate, phosphate and silica good for phytoplankton growth is 16:16:1 [21].

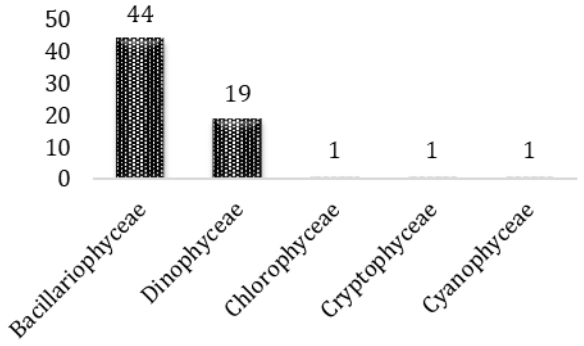

Figure 2. Classes and number of phytoplankton species found in Jembrana coastal waters

The nutrient content in the sea is influenced by the flow of water from land through rivers or the influence of upwelling phenomena [22]. The condition of the seas around Perancak Beach, Jembrana Regency, is influenced by input from the Ijo Gading River estuary. Nutrient elements carried from rivers enter the estuary waters and cause an increase in water fertility. Phytoplankton will grow well in estuary ecosystems that are rich in nutrients. There are 31 phytoplankton genera from 4 divisions in the waters of the Sei Carang estuary [23].

Table 1. Distribution of Phytoplankton Species at each observation station

	Class/Species	St. 1	St. 2	St. 3	St. 4	St. 5
I. Bacillariophyceae						
1	*Amphora spectabilis*	-	-	+	-	-
2	*Bacteriastrum comosum*	-	+	+	+	+
3	*Chaetoceros* sp.	+	-	-	-	-
4	*Chaetoceros affinis*	+	+	+	+	+
5	*Chaetoceros curvicetus*	-	-	+	+	-
6	*Chaetoceros decipiens*	+	+	+	+	+
7	*Chaetoceros delicatum*	+	-	-	-	-
8	Chaetoceros laciniosum	-	-	-	-	+
9	*Chaetoceros messanensis*	+	-	-	-	-
10	*Chaetoceros peruvianus*	-	+	+	-	-
11	*Choretron hystrix*	+	+	+	-	-
12	*Coscinodiscus sp.*	-	-	-	+	-
13	*Coscinodiscus centralis*	+	-	-	-	-
14	*Coscinodiscus radiatus*	-	+	+	-	+
15	*Cyclotella* sp.	+	+	-	-	-
16	*Dactyliosolen blavyanus*	+	-	-	-	-
17	*Dactyliosolen* sp.	-	-	-	-	+
18	*Ditylum* sp.	-	-	-	+	-
19	*Eucampia* sp.	-	-	-	-	+
20	*Flagilariopsis cylindrus*	-	+	-	-	-
21	*Fragilaria oceanica*	+	-	-	-	-
22	*Lauderia annulata*	-	+	-	+	+
23	*Leptocylindricus danicus*	-	-	+	+	+
24	*Leptocylindricus minimus*	-	+	-	-	-
25	*Melosira* sp.	-	+	+	+	-
26	*Meuniera membranacea*	+	+	-	+	-
27	*Navicula cancelate*	+	-	-	-	-
28	*Navicula* sp.	-	+	+	-	+
29	*Nitzschia* sp.	-	+	+	+	+
30	*Nitzschia longissima*	+	-	-	-	-
31	*Odontella mobilensis*	-	+	+	-	+
32	*Odontella sin*	-	-	+	-	-
33	*Odontella sinensis*	+	+	+	+	-
34	*Planktoniella chilensis*	+	-	-	-	-
35	*Planktoniella sol*	-	+	-	-	+
36	*Pseudonitzschia australis*	+	-	-	-	-
37	*Pseudonitzschia* sp.	-	-	+	-	-
38	*Rizhosollenia alata*	+	+	+	+	+
39	*Rizhosollenia bergonii*	-	-	-	+	+
40	*Sceletonema costatum*	+	-	-	-	-
41	*Synedra* sp.	-	+	-	-	-
42	*Thalasionema bacilare*	+	-	-	-	-
43	*Thalassionema nitzschioides*	-	+	-	+	-
44	*Thalassiosira oestupii*	+	-	-	-	-
II. Dinophyceae						
45	*Alexandrium tamarense*	-	+	-	+	-
46	*Ceratium contrarium*	-	+	-	-	-
47	*Ceratium furca*	+	+	+	+	-
48	*Ceratium fusus*	-	+	-	-	-
49	*Ceratium humile*	-	-	-	+	-
50	*Ceratium longirostrum*	-	+	-	-	-
51	*Ceratium trichoceros*	+	-	-	-	-
52	*Ceratium tripos*	+	+	-	-	-
53	*Ceratium vulture*	-	+	-	-	-
54	*Dinophysis tripos*	+	-	-	-	-

	Class/Species	St. 1	St. 2	St. 3	St. 4	St. 5
55	*Dynophysis caudata*	-	+	+	+	-
56	*Noctiluca scintillans*	+	-	-	-	-
57	*Peridinium oceanicum*	+	+	-	-	-
58	*Peridinuim depresum*	-	+	-	-	-
59	*Phyrophacus horologicum*	-	-	+	-	+
60	*Prorocentrum micans*	+	-	-	-	-
61	*Prorocentrum* sp.	-	+	-	-	-
62	*Protoperidinium depressum*	-	-	+	+	-
63	*Pyrocyctis nautiluca*	-	+	-	-	-
III. Chlorophyceae						
64	*Closterium* sp.	-	+	-	-	-
IV. Cryptophyceae						
65	*Rhodomonas* sp.	-	+	-	-	-
V. Cyanophyceae						
66	*Trichodesmium thiebautii*	+	+	+	+	+

Information:
(+) : Found
(-) : Not Found

Figure 3 shows the abundance of phytoplankton at each observation station. The abundance of phytoplankton was found to vary at each station, ranging from 36 – 297 individuals/L. The highest abundance was obtained at station 2, followed by station 1, station 4, station 3 and station 5. This abundance value is likely due to the influence of nutrient input from the river estuary.

In the waters of the Bali Strait, two classes of phytoplankton, namely Bacillariophyceae and Dinophyceae, were found to be dominant, with the highest abundance value occurring in transition season II with 51,405 cells/L, which was dominated by the *Rhizosolenia stolterfothii*. It was further explained that the diatom class (Bacillariophyceae) was the dominant class with 95.9%, but the Diversity Index was in the low category (H' = 0.53) [20].

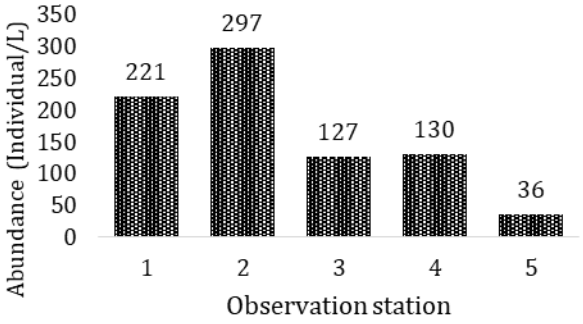

Figure 3. Abundance of phytoplankton at each station

Research [24] in August, September and November 2009 in Jakarta Bay also showed that the dominant species of the Bacillariophyceae class were Chaetoceros, Rhizosolenia, and Skeletonema found at all stations and observation times. Research [25] also reported the dominance of Rhizosolenia in the waters of the East coast of Belitung.

Based on the observations, several phytoplankton species were dominant and widely distributed at all observation stations. Most of the dominant and widespread phytoplankton come from the classes Bacillariophyceae (genus Rizhosollenia, Coscinodiscus and Chaetoceros), Dinophyceae (genus Ceratium and Dinophysis) and Cianophyceae (genus Trichodesmium). The dominance of phytoplankton species is influenced by physical and chemical factors in waters [21]. These factors interact complexly and create the dynamics of phytoplankton populations in the water.

The Bacillariophyceae class, usually called Diatoms, are the natural food of fish, crustaceans and shellfish. One a genus of this class, commonly used as natural food for Rotifera, pearl oysters and shrimp larvae, is Chaetoceros [4,5].

Apart from being useful as natural food, the species of phytoplankton found in the coastal waters of Jembrana Regency also have the potential to cause danger if there is a population explosion (Harmfull Algae Blooms). This potential danger usually comes from the Cianophyceae class (genus Trichodesmium). Phytoplankton population explosions are commonplace in Indonesia. Eutrophication is one of the factors causing the population explosion. The population explosion causes harm to fish and shellfish [9]. Fatal incidents in shrimp ponds, fish farms and coral reefs often occur in Indonesia [8].

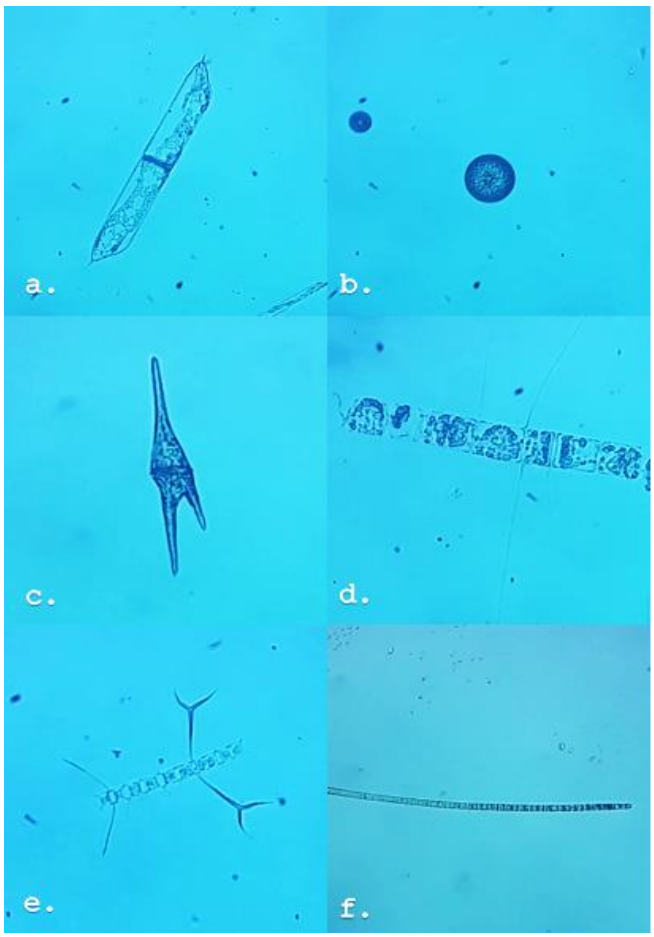

Figure 4. The dominant species of phytoplankton found at the observation station (a. *Rizhosollenia alata*; b. *Coscinodiscus radiates*; c. *Ceratium furca*; d. *Chaetoceros decipiens*; e. *Chaetoceros messanensis*; f. *Trichodesmium thiebautii*)

Phytoplankton Ecological Index

The phytoplankton diversity index value found at the research location varied at each station, ranging between 2.61 – 2.83 (Table 2). The diversity index value obtained was greater than other locations in Bali waters, as reported by [16], who reported phytoplankton diversity index (H') values ranging from 0.31 – 1.47 in the waters of Benoa Bay. A similar thing was also reported by [17], who researched the seas around the ports in Bali (Pengambengan, Benoa and Amed), reporting a diversity index value of 1.22. Research [18] conducted around Serangan Island found that the phytoplankton diversity index value ranged from 0.2 – 0.98. This diversity index value can indicate the condition of an ecosystem where the higher the value, the better it will be cause the species composition is evenly distributed and no one dominates [15].

Table 2. Phytoplankton Ecological Index in Jembrana Coastal Waters

Ecological Index	St. 1	St. 2	St. 3	St. 4	St. 5	info
Diversity (H')	2.81	2.61	2.78	2.83	2.70	Moderate
Evenness (e)	0.83	0.72	0.90	0.93	0.95	Evenly
Dominance (C)	0.09	0.13	0.08	0.07	0.08	Not dominant

Apart from the Species Diversity Index, the Phytoplankton Species Evenness Index (e) value was also calculated. The phytoplankton species evenness index value ranges from 0.72 – 0.95, which indicates that the phytoplankton taxa are evenly distributed. This value is higher than that of other locations in Bali waters. Research conducted by [16] reported that the phytoplankton species uniformity index value in the waters of Benoa Bay ranged from 0.14 – 0.58, while around the fishing harbour in Bali, it was 0.91 [17].

The value of the Species Evenness Index (e) is strengthened by the Species Dominance Index (D) value, where the Species Dominance Index (D) value ranges from 0.07 – 0.13, which indicates that there are no dominant species. The values obtained are lower compared to other locations in Bali [16]. A phytoplankton dominance index ranging from 0.31 – 0.89 in the waters of Benoa Bay, while in the waters around the fishing port in Bali, it was 0.36 [17]

Conclusion

Based on the research and discussion results, it can be concluded that 66 phytoplankton species were classified into five classes in the waters of Jembrana, Bali. The Bacillariophyceae class was found with the highest number of species (44 species), followed by the Dinophyceae (19 species), Chlorophyceae (1 species), Cryptophyceae (1 species), and Cyanophyceae (1 species). Based on the results of calculating phytoplankton abundance, various abundance values were obtained at each observation station. Station 2 has the highest abundance of phytoplankton with 297 individuals/l followed by Station 1 (221 individuals/l), Station 4 (130 individuals/l), Station 3 (127 individuals/l), and Station 5 (36 individuals/l). The species diversity index (H') ranges from 2.61 - 2.83, the dominance index (C) ranges from 0.07 - 0.13, and the evenness index (e) ranges from 0.72 - 0.95. The ecological index value shows that the phytoplankton community in Jembrana coastal waters is included in moderate diversity, not dominant and evenly distributed. The ecological index value shows that the water quality is categorized as moderately polluted.

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