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Original Paper

Phytoplankton Diversity as Ecological Indicator in Jimbaran Bay Waters

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***Abstract*:** A study was carried out to evaluate the ecological condition in Jimbaran Bay Waters by using Phytoplankton Diversity Index. The study was conducted at Balangan, Pemuda, Jimbaran, Kedonganan, Kelan and Segara Beach located in Jimbaran Bay. Shannon-Wiener diversity index was used to analyze the ecological condition, supported by analysis on water quality including dissolved oxygen (DO), biological oxygen demand 5 days (BOD5), water pH, and water salinity. There were 51 species of phytoplankton classified to 5 classes had been observed from this study: Bacillariophycae, Cyanophyceae, Zygnemophyceae, Dinophyceae, and Chlorophyceae. Balangan beach showed higher diversity index (H) and evenness index (E) (H = 1.19; E = 0.29) compared to the other site (Pemuda: H = 0.89, E = 0.25; Jimbaran: H = 0.89, E = 0.26; Kedonganan: H = 0.96, E = 0.28; Kelan: H = 0.85, E = 0.20; and Segara: H = 0.91, E = 0.33). However, overall ecological condition showed diversity index more than 1 (H = 1.44; E = 0.27). Measurement of water quality showed that the highest quality of water was shown by Balangan Beach (DO 5.2 mg/L, pH 7.2, salinity 29 ppt, and BOD5 0.9 mg/L), while the lowest was shown by Kelan Beach (DO 4.2 mg/L, pH 7.2, salinity 29 ppt, and BOD5 2.9 mg/L). Result of the study showed that ecological status of Jimbaran Bay Waters was having moderate diversity, sufficient productivity, and medium ecological pressure (pollution).

***Keywords*:** Phytoplankton; Diversity; Jimbaran Bay; Ecological; Indicator

1. Introduction

During the last decade, the importance of phytoplankton diversity to be one of the most water environmental indicators has been gradually applied. Coastal environmental condition, either biotic or a biotic is contribute substantially to the abundant and diversity of phytoplankton in the waters. A lot of

phytoplankton species are known to have limited coastal environmental tolerance range for their live. Coastal environment show their difference in physical, chemistry and biological element such as depth, tidal mixing or nutrient loadings and these can lead to complex phytoplankton dynamics (Cebrian and Valiela, 1999). This is influenced by the fact that water quality of coastal environment around worldwide is clearly changing in response to land based activity increase such as fertilizer utilization, land clearing, coastal reclamation, water discharge, and ecotourism activity. This could affect either in spatial or temporal taxonomic distribution and abundant of phytoplankton (Kiteresi et al, 2012).

Plankton, typically phytoplankton, has a relative short live compared to the other biota in the water. It could respond the quick environmental perturbations such as water pollution caused by many pollution source (Osore and Daro, 2003). On the other hand, Zingone et al (1995) had reported that phytoplankton has a periodicity affected by different source of nutrient send by the land. Since that, phytoplankton communities could be utilized to be the biota representing the changes in the ecological environment (Legendre and Legendre, 1998).

The main land based activity around Jimbaran Bay water is ecotourism activity, such as presented in Balangan, Pemuda, Jimbaran, Kedonganan, Kelan and Segara Beach. The increase in hotel room demand for ecotourism could accelerate the production of waste water produced by hotel industry. A study performed by Sundra (2011) showed that there is a trend of ecological pressure to the Jimbaran Bay waters. Since the Government of Bali Province Regulation established on regulation number: 7/Pergub/2007, the analysis on coastal water quality showed a light pollution around Badung Regency including Jimbaran Bay. Therefore, an analysis on the ecological pressure caused by domestic pollution such as hotel industry around Jimbaran Bay Waters is necessary to be conducted. In this paper, we clearly examine the role of phytoplankton and their diversity in Jimbaran Bay coastal water to the ecological and environmental pressure.Kaufman (1989) Main text paragraph

2. Material and Method

This study was conducted in coastal region of Jimbaran Bay. Sampling was carried out in the intertidal area of the bay, including: Balangan Beach, Pemuda Beach, Jimbaran Beach, Kedonganan Beach, Kelan Beach and Segara Beach. A random determination was used to determine the location used in this study. Phytoplankton samples were collected in rainy season, December 2014. These were collected based on method used by Keteresi et al (2012), whether phytoplankton concentrated samples filtered by using a 20 μm phytoplankton net from a volume of 20 liters water. Thus, a volume of 150 ml water samples containing concentrated phytoplankton were fixed in 5% lugol solution in order to preserved the morphological condition of the phytoplankton. After that, it was kept undisturbed up to three days till showed the completed the sedimentation.

Concentrated phytoplankton samples, then, were counted by using a haemocytometer under microscope visualization. Firstly, a cover glass was placed over both of the haemocytometer. Thus, with a soft motion, the concentrated phytoplankton samples were gently inverted approximately 10-20 times to ensure the sample was mixed thoroughly. Each chamber of haemocytometer was loaded by holding pipette at a 30 to 45 degree angle with the open dispensing tip in the V-shaped glass, and allowing the pipette tip to touch the slot slowly when drop the sample. As a result, a capillary action affected the sample to fill the chamber. The number of phytoplankton cell and the number of squares counted, then, were noted after observation under microscope. The average of number cells per square could be calculated by using formula bellow:

$$P = \frac{\sum N}{\sum S} \quad (1)$$

P represents the average number of cells per square, N represent the total cells had been observed, and S represent number of large 1 mm squares. The average cell number, then, was multiplied by 10,000 in order to obtain the final number cells per ml.

The data of phytoplankton were expressed as the ecological indicator in order to describe the community and structure of phytoplankton around the coastal environment. The parameters used in this study were abundance, diversity, and evenness index of phytoplankton. Species abundance could be taken from the total number taxa found in the samples. Thus, diversity of the phytoplankton were calculated by adapted method developed by Shannon (1948) using formula bellow:

$$H = -\sum \frac{ni}{N} \log \frac{ni}{N} \quad (2)$$

H represents the diversity index of the phytoplankton, *ni* represent the number of the individuals of the i^{th}, and *N* represent the total number of individuals. On the other hand, the evenness index was calculated using formula bellow:

$$E = \frac{H}{\ln S} \quad (3)$$

H is the Shannon Wiener's species diversity index, while *S* represents the species richness (number of species found).

The measurement on water quality around Jimbaran Bay Waters had performed on Dissolved Oxygen (DO), Biological Oxygen Demand 5 Days (BOD_5), Water Acidity Level (pH) and Water Salinity. DO and BOD5 was measured in mg/L by using Dissolved Oxygen Meter (Lutron DO 5509) registered from Lutron Electronic Enterprise Co. Ltd which have accuracy range of ± 0.4 mg/L (after calibration within 23 ± 5°C). Water acidity level (pH) during the study was measured by using Pen pH meter (Lutron pH-222) registered from Lutron Electronic Enterprise Co. Ltd which have accuracy range of ± 0.02 pH (after calibration). In addition, water salinity was measured in ppt by using Hand-held Refractometer (Atago-MASTER-S/MillM 2493) registered from Atago Co. Ltd.

3. Results and Discussion

3.1. Result

A total of 51 phytoplankton species which was classified to 5 classes had been encountered during this study. The class of phytoplankton had been observed from the location were Bacillariophyceae, Cyanophyceae, Zygnemophyceae, Dinophyceae, and Chlorophyceae. The species from class of Bacillariophyceae showed the highest number compared to the other species of class groups. There were a total 34 number of species had been shown from the observation. The class of Cyanophyceae, Chlorophyceae and Dynophyceae showed lower result, these are 6, 5, and 4 species, respectively. In contrast, the species from class of Zygnemophyceae showed the lowest number which showed 2 species only (Table 1).

Table 1. Species of Phytoplankton Classified based on the Class Groups

Class	Σ Species	Phytoplankton Species
Bacillario-phyceae	34	*Nitzschia* sp, *Synedra* sp, *Biddulphia* sp, *Isthmia* sp, *Tribonema* sp, *Skeletonema* sp, *Amphora* sp, *Rhizosolenia* sp, *Spirulina* sp, *Cyclotella* sp, *Chaetoceros* sp, *Melosira* sp, *Amphipleura* sp, *Pinnularia* sp, *Navicula* sp, *Surirella* sp, *Striatella* sp, *Bellerochea* sp, *Paralia* sp, *Coscinodiscus* sp, *Ceratium* sp, *Entomoneis* sp, *Licmophora* sp, *Eunotia* sp, *Epithemia* sp, *Corethron* sp, *Asterionellopsis* sp, *Thalassionema* sp, *Scolioneis* sp, *Denticulopsis* sp, *Bacillaria* sp, *Leptocylindrus* sp, *Guinardia* sp, *Fragillaria* sp, *Amphiphora* sp, *Cerataulina* sp.
Cyanop - hyceae	6	*Spirulina* sp, *Lyngbya* sp, *Stichosiphon* sp, *Oscillatoria* sp, *Dactylococcopsis* sp, *Gomphasphaeria* sp.
Zygnemo-phyceae	2	Desmidium sp, Gonatozygon sp.
Dino-phyceae	4	*Ceratium* sp, *Dynophysis* sp, *Gonyaulax* sp, *Peridiniopsis* sp.
Chloro-phyceae	5	*Actinastrum* sp, *Pandorina* sp, *Ankitrodesmus* sp, *Chlamydomonas* sp, *Kirchneriella* sp.

Table 2. Diversity and Evenness Index of Phytoplankton Species in Jimbaran Bay Waters

Class	Balangan		Pemuda		Jimbaran		Kedonganan		Kelan		Segara		Jimbaran Bay	
	ΣSp	ΣInd	ΣSp	ΣInd	ΣSp	ΣInd	ΣSp	ΣInd	ΣSp	ΣInd	ΣSp	ΣInd	ΣSp	ΣInd
Bacillariophyceae	15	46	9	28	5	16	8	24	8	53	5	9	34	176
Cyanophyceae	4	10	2	3	1	1	0	0	1	1	1	1	6	16
Zygnemophyceae	2	3	0	0	0	0	0	0	0	0	0	0	2	3
Dinophyceae	0	0	1	1	0	0	1	1	1	10	1	1	4	13
Chlorophyceae	0	0	1	1	0	0	1	3	1	2	2	5	5	11
Total	21	59	13	33	6	17	10	28	11	66	9	16	51	219
Diversity Index (H)	1.19		0.89		0.89		0.96		0.85		0.91		1.44	
Similarity Index (E)	0.29		0.25		0.26		0.28		0.20		0.33		0.27	

Among all of site location, phytoplankton diversity index shown various result. The highest diversity index had shown by Balangan Beach (H = 1.19; E = 0.29) which has a number 59 of total individuals abundance. On the other hand, the lowest diversity index of phytoplankton species had shown by Kelan Beach (H = 0.85; E = 0.20) which has a 66 number of total individuals abundance. Based on the result, there was one only site location showed diversity index up to 1 (Balangan Beach), while another site had shown diversity index less than 1. It could be concluded that Balangan Beach showed a middle level of ecological condition, having moderate diversity, sufficient productivity, and medium ecological pressure. On the contrary, the other site location (Pemuda, Jimbaran, Kedonganan, Kelan and Segara Beach) showed a low level of diversity, poor of productivity indicated the present of high pressure to the ecological condition caused unstable ecosystem. However, even almost all of the site location showed a low diversity index, overall site in average had shown high diversity index (H = 1.44; E = 0.27) (Table 2).

Observation on the water quality among all of site location showed various result. Highest dissolved oxygen had shown by Balangan Beach (5.2 mg/L), while the lowest were shown by Jimbaran and Kelan Beach (4.2 mg/L). On the other hand, Pemuda and Segara Beach showed a moderate result which showed dissolved oxygen at 4.8 and 4.9 mg/L, respectively. It was correlated with the biological oxygen demand showed by each site location. Biological oxygen demand at Kelan Beach showed as the highest (2.5 mg/L) compared to the other location, while the lowest were shown by Pemuda, Kedonganan, and Segara Beach (1.2 mg/L). Water acidity level (pH) and salinity had also been observed in this study. Water acidity level in all of location was ranging from 7-7.2 which showed that this water is in normal condition. Thus, observation on the water salinity had shown no difference on the result. Samples of water taken from all of site location showed the same number 29 ppt (Table 3).

Table 3. Water Qaulity (DO, BOD, pH, and Salinity) of Jimbaran Bay Waters

Variable	Balang-an	Pemuda	Jimba-ran	Kedonga-nan	Kelan	Segara
DO (mg/L)	5.2	4.8	4.2	5	4.2	4.9
pH	7.2	7	7	7	7.2	7
Salinitas (ppt)	29	29	29	29	29	29
BOD5 (mg/L)	0.9	1.2	1.9	1.2	2.5	1.2

3.2. Discussion

The most important characteristic of coastal in intertidal zone is its high biodiversity. Odiete et al (2003) had reported their study that chemical measurements reflect water quality at a certain time, while biological assessment reflects conditions existed in a certain environment for long time period. Phytoplanktons present in Jimbaran Bay were belonging to Bacillariophyceae, Cyanophyceae, Chlorophyceae, Dinophyceae, and Zygnemophyceae.

Species of Bacillariophyceae (Diatom) were known to be highest abundant in this area. It might be caused by the influence of any water quality parameters assemblages the marine environment at Jimbaran Bay. Regarding to the water quality visualized by this area, there is a correlation between the present of organic compound, DO, BOD5 and abundant of phytoplankton in this area. Based on a study conducted by Sundra (2012), there was a report that Jimbaran Bay was highly potential to be polluted by organic pollutant. The study reported that NH3 and PO4 composition in this area was over the limit determined by the national regulation. Unfortunately, these elements have commonly known as the source of eutrophication in the environment. Phytoplankton type diatom was associated with more eutrophic conditions (Matsuoka, 2003), synergy to the condition around Jimbaran Bay. Bacillariophyceae was commonly found at marine environment (Simon et al, 2009) and were able to tolerate the unfavorable ecological conditions for a while by moving towards upper mixed layer and then move down to the deeper part of the water column (Smetacek, 1985). Thus, Bacillariophyceae species showed a relation on their abundant related to the high level of water pH in all location. The highest number of diatom species was shown by Chaetoceros sp and Skeletonema sp. Lo et al (2004) reported on their study that the diatom species, Chaetoceros sp was known to be present in warm water and was a neritic species which its abundance is increased along the increase in water temperature. Chaetoceros sp and Skeletonema sp was a centric diatom which have euryhaline characteristic and were considered as bioindicator species of water pollution and eutrophication.

Beside the effect of N and P composition to the phytoplankton abundant in the water, effect of water pH on phytoplankton had also been observed. Variations in pH could give either in direct or indirect effect to the growth of phytoplankton. The change of pH in the water is substantially changing the distribution of carbon availability and essential nutrient in the water. The present of carbon source in the water, as commonly known, were affecting the level of primary productivity (Chen and Durbin, 1994). The Balangan and Kelan Beach showed high abundant in phytoplankton individuals number. This was relevant to the high level of water pH in these locations. Goldman (1982) stated that phytoplankton growth was potentially accelerated by the high level of water pH. Similar to the role of phytoplankton species succession in freshwater environment, the species succession in marine environment was might be also determined by the ability of certain species to proliferate at high water pH presumably due to their tolerance of low CO2 level (Brock, 1973; Goldman and Shapiro, 1973; Shapiro, 1973). On the other hand, water pH have an indirect effect to the phytoplankton structure and community in marine environment. Philips (1972) reported that there will be a corresponding shift in hydrogen ion concentration towards the alkalinity and increase in the level of dissolved salt during the increase in the turbidity. Thus, it will promote a coagulation process on fine particulate matter.

Water salinity also plays an important role on the phytoplankton growth. Marine phytoplankton species was commonly showed a broad range of salinity tolerance to their growth Brand (1984). However, increase in water salinity level could slow the growth of phytoplankton (Marcelli, 2006). Balzano et al (2011) reported that a certain of diatom species (Skeletonema sp) showed grew well at salinities range of 10-35 ppt. Moreover two species, Skeletonema costatum and Skeletonema subsalsum showed growth between salinities of 0 and 35 ppt and exhibited very short intercellular processes when cultured in low salinity environment. Similar to this result, a study reported by Ahel et al (1996) showed that there were three kind of diatoms predominantly present on high range of environmental salinity tolerance (Skeletonema costatum, Chaetoceros sp, and Nitzschia sp). Beside the effect of water salinity to the community structure of phytoplankton, the effect of

dissolved oxygen present on water was also been observed. DO concentration in the water column is an environmental parameter that is crucial for the successful development of many pelagic organism (Miller et al, 2002). Hypoxia, a condition of low dissolved oxygen in the water (<2 mg/L), is enormously affected the community structure of phytoplankton in the water. On the individual levels, it could cause physiological changes and then alters the lifecycle performance, growth capacity and reproductive success which indirectly causes a change in species composition, trophic relation and productivity (Ekau et al, 2010). In shallow water, such as seen at the coastal region of Jimbaran bay, nutrient input and sedimentation is often high. Therefore, organic matter will be accumulated on the seafloor and could causes the water column to turn hypoxic or anoxic (Helly and Levin, 2004). The data result showed in Jimbaran bay waters seen to be in moderate condition which showed dissolved oxygen more than 5 mg/L in average. It could be concluded that water quality in Jimbaran Bay is in good condition, even there were any location showed a low concentration of dissolved oxygen. The ecological condition such as showed in dissolved oxygen and water salinities might cause the environment to be in a good condition. High diversity of phytoplankton species in overall site location might be caused by this condition.

4. Conclusions

An ecological status of Jimbaran bay waters was determined after analysis on the phytoplankton diversity in this location. There were 51 phytoplankton species found in the location, which was classified to 5 classes: Bacillariophyceae, Cyanophyceae, Zygnemophyceae, Dinophyceae, and Chlorophyceae. The Bacillariophyceae (diatom) species Chaetoceros sp and Skeletonema sp were known to be the highest in number of the species among location. Analysis on the ecological condition using phytoplankton species diversity showed that Jimbaran bay waters was having middle level of ecological condition, a moderate diversity, sufficient productivity, and medium ecological pressure.

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