The abundance and spatial distribution of plankton communities in Perancak Estuary, Bali

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Abstract. Perancak estuary is a productive ecosystem and has important role in the balance of nature and the life of local communities. However, research about water quality and organisms in Perancak estuary is still low, especially on plankton abundance and distribution. The aim of this research was to analyze the abundance and spatial distribution of plankton communities. The research was conducted by field surveys in November 2015, samples were taken from 3 stations representing upstream (S1), stream (S2) and downstream (S3). Plankton sampling was carried out by filtering water samples as much as 100 liters of plankton net with mesh size 25µm, diameter 31 cm, and length 80 cm. Filtered samples were stored in the sample bottle and the preserved with 1 ml of 4% formaldehyde. The result showed, an abundance of phytoplankton ranged between 33,600 – 3,002,400 cell/m^3 and zooplankton between 6,000-57,000 ind/m^3. Total of 6 genera of phytoplankton and 14 genera of zooplankton was recorded during the research period. The ecological index showed that species diversity of plankton in Perancak estuary was categorized as low diversity. Plankton abundance in S1 which located in Loloan River is higher than others. Its caused by anthropogenic waste from agriculture, households and industrial waste.

1. Introduction

Perancak estuary is located in District Negara, Jembrana District, Bali has a total area of 876 ha, in the form of the pond either active or inactive with an area of 390 ha and mangrove forests with an area of 78.6 ha. Perancak estuary has distinctive characteristics which the water bodies affected by the intake of salty water of the Strait of Bali and fresh water from a river that flows in it, one of which is the River Loloan. Region Perancak estuary habitats for producers, consumers and consumer peaks in the food chain.

Plankton is one of the biological parameters that is influenced by other parameters and is a very important link in supporting the life of other organisms [1, 2]. Plankton is microscopic organisms floating in the water column or has a very weak swimming ability; the movement is always affected by the mass movement of water [2, 3]. The abundance of phytoplankton in the waters affected by several environmental parameters and physiological characteristics. The composition and abundance of phytoplankton will change at various levels in response to changing environmental conditions, whether physical, chemical and biological [4].

The existence of plankton can be used as one of the indicators of water quality. Phytoplankton is a biological indicator for evaluating the quality and fertility of aquatic ecology [5, 6]. Waters with nutrient content, both nitrate, phosphate, and silicate will enrich the estuary area because the nutrients are needed for plankton growth. Information on the plankton community structure in the Perancak still rare. Therefore, this

study aims to analyze the diversity and structure of the plankton community to describe the condition of the water condition in the Perancak Estuary.

2. Materials and Methods

The study was conducted in November 2015 representing the transitional season in the Perancak Estuary. Perancak Estuary is located in Jembrana district, Bali province. The choice of sampling stations was conducted according to the anthropogenic activities (S1), pond areas (S2), and gradient of salinity (S3) (figure 1). Data collection when high tide is assumed to be a mixing between sea water and freshwater that will affect the abundance of plankton species [7].

Plankton samples were taken at the surface layer at three observation stations using net plankton with mesh size 25 μm, diameter 31 cm, and length 80 cm, based on SNI 06-3963-1995 and Greenberg method [8]. Plankton samples were obtained from 100 liters of filtered water and concentrated to 30 ml. The water sample was placed in a white or dark film bottle, and 4% formalin added. Measurements of water quality parameters were carried out by handheld Multi-Parameter Water Quality Checker (WQC) -24. Parameters taken include temperature, salinity, pH, DO, phosphate, silicate, and nitrate referring to SNI 6989.57-2008.

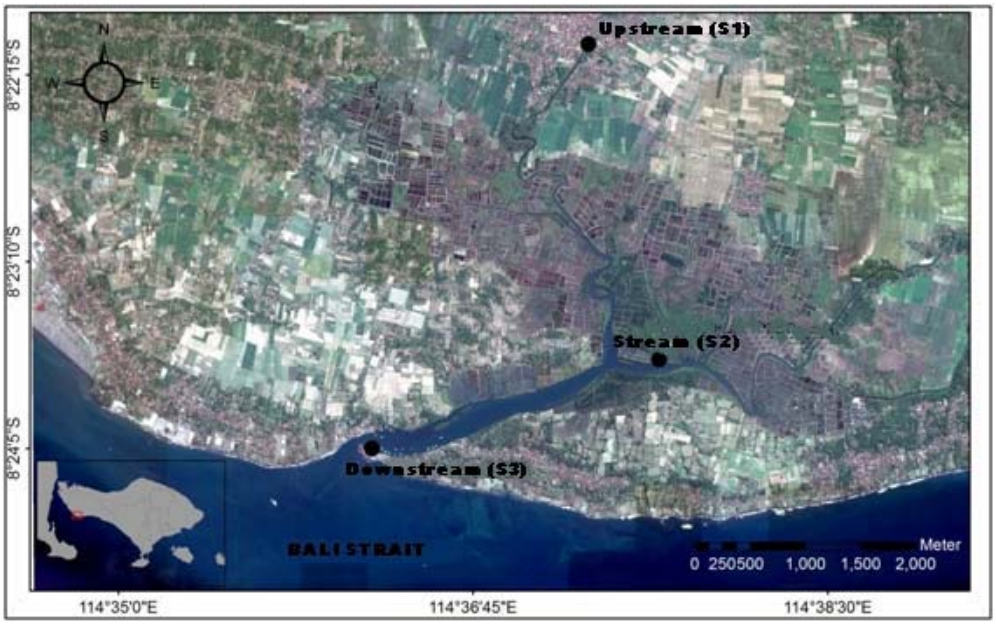

Figure 1. The study area.

Plankton identified by using Optica B310 binoculars microscope with 100 times magnification. 1 ml of the homogenized samples, dripped on Sedgewick Rafter and covered with cover glass, then identified and calculated the abundance. Identification of plankton refers to [9] plankton identification book. The abundance of plankton calculated referring to APHA (2005):

$$N = \frac{1}{Vd} \times \frac{Vt}{Vs} \times n \quad (1)$$

Description: N = Plankton abundance (cell/m^3 or ind/m^3); Vd = volume of filtered water sample (m^3); Vt = volume of filtered sample (ml); Vs = concentrate volume of Sedgwick Rafter Counting Cell (ml); n = number of observed plankton.

Diversity index was based on Shannon-Wiener index [10] with the following formula:

$$H' = -\sum_{i=1}^{n} pi \ln pi \quad (2)$$

Description: H' = Shannon-Wiener diversity index; $pi = ni/N$; ni = number of individual species-ith; N = total number of individuals

Evenness index was determined using the following formula [11]:

$$E = \frac{H'}{Hmax} \quad (3)$$

Description: E = Evenness index; H' = Shannon-Wiener diversity index; H_{max} = ln S; S = number of genera.

Dominance index was determined using the following formula [11]:

$$D = \sum_{i=1}^{s} \left(\frac{ni}{N}\right)^2 \quad (4)$$

Description: D = Simpson dominance index; ni = number of individual species-ith; N = total number of individuals; S = number of genera

3. Result and Discussion

3.1 The water quality of Perancak Estuary

The physic-chemical water quality of Perancak Estuary shows on table 1.

Table 1. The water quality of perancak estuary.

Parameter	Station		
	Upstream (S1)	Stream (S2)	Downstream (S3)
Temperature (°C)	35.03±0.12	32.70±0.00	30.13±0.20
Salinity (ppt)	16.27±0.15	33.70±0.00	34.07±0.12
pH	7.56±0.08	7.85±0.01	8.05±0.02
DO (mg/l)	5.13±0.10	3.42±0.07	4.07±0.05
Phosphate (mg/l)	0.43±0.00	0.25±0.00	<0.001±0.00
Silica (mg/l)	2.78±0.05	0.90±0.02	<0.001±0.00
Nitrate (mg/l)	<0.001±0.00	<0.001±0.00	<0.001±0.00

Based on table 1. the range of surface temperature from upstream to downstream is 30.13 - 35.03°C. In general. the salinity at the Perancak Estuary measured in November ranges from 16.27 - 34.07‰. where the lowest salinity is at upstream which Loloan River (16.27 ‰) and highest in downstream (34.07 ‰). Salinity fluctuations in the estuary have a profound effect on plankton distribution [12. 13. 14. 15]. The lowest average pH was found in the upstream (7.56). and the highest was in downstream (8.05). According to [16]. the ideal pH range for plankton life ranges from 6.8 to 8.0. Dissolved Oxygen (DO) at stream is lower (3.42 mg/l) than in the upstream (5.13 mg/l) and downstream (4.07 mg/l). Phosphate is often regarded as a limiting factor of phytoplankton growth in natural waters [17. 18. 19]. The measured phosphate values range from 0.25 to 0.43 mg/l and still within the optimum range for plankton growth. The phosphate values in the upstream are higher than the stream and downstream; it caused by the upstream is near from settlements that allow industrial waste disposal. household waste. and agricultural waste. The content of silicate in upstream is higher than two other stations that are 2.78 mg/l. Silica nutrients are needed and have an effect on the growth process and the development of the life of several kinds of phytoplankton such as diatoms and

silicoflagellates for the formation of their cell. The nitrate content in the three research sites is almost undetectable; this is probably due to the absence of nutrient input from the land.

3.2 Phytoplankton abundance and distribution

The ranges of phytoplankton abundance in the Perancak Estuary is 42,000 to 3,002,400 cells/m^3. The highest abundance is found in the upstream and the lowest in downstream. The abundance of phytoplankton in aquatic can fluctuate in type and amount due to differences in nutrient content. Predation by zooplankton or herbivorous fish and tidal occurrence of sea water. Tides can affect plankton abundance and distribution. In high tide conditions. The flow of sea water to the river carrying the phytoplankton of sea water (Diatom) in it mixed with river water in which there is freshwater phytoplankton and vice versa. This is what causes Diatoms are found in the upstream which adds to the abundance of phytoplankton on the upstream and the discovery of Cyanophyceae at the stream and downstream.

The phytoplankton abundance in Perancak Estuary varied between 33,600 – 3,002,400 cell/m^3. Table 2 shows *Oscillatoria* sp. was dominance and distributes equally in all stations. However. the abundance of *Oscillatoria* sp. Has not reached endangers for the other lives organisms because according to [20] *blooming* will occurs when the abundance reaches $5x10^5$ to $2x10^6$ cells/l. Differences in the abundance of phytoplankton in Estuary Perancak are closely related to the physics-chemical conditions of the waters. According to [21]. Nutrients that get into the aquatic environment such as phosphate, nitrate, silica and ammonia will affect the development of phytoplankton and zooplankton.

The abundance of *Oscillatoria* sp. Which is high in the upstream can be caused by the high nutrients as a result of the runoff the organic materials coming from households. Ponds and farming activities. Consumption of fertilizer on agricultural supplies nitrate and phosphate to the river through washing and soil erosion [22].

Table 2. The abundance of phytoplankton in Perancak Estuary.

No.	Class of Phytoplankton	Density (cell/m^3)		
		Upstream (S1)	Stream (S2)	Downstream (S3)
	Cyanophyceae			
1	*Oscillatoria* sp.	2,995,200	33,000	42,000
	Diatom			
2	*Biddulphia* sp.	900	300	-
3	*Cocconeis* sp.	1,500	-	-
4	*Coscinodiscus* sp.	600	-	-
5	*Pleurosigma* sp.	2,100	-	-
6	*Thalassiosira* sp.	2,100	300	-
	Density (cell/m^3)	3,002,400	33,600	42,000

The phytoplankton composition in Perancak Estuary consists of 6 species classified into two classes: Diatoms and Cyanophyceae (figure 2). Judging from the physical factors the waters Estuary Perancak is a suitable habitat for the growth of Oscillatoria sp. Oscillatoria is an important member of Cyanophyceae because it can perform photosynthesis activities. Cyanophyceae live in neutral or alkaline waters and are not found in waters with a pH less than 4 [23]. This corresponds to a pH value in the Perancak Estuary that ranges from 7.56 to 8.05. Optimal temperature conditions also support the growth of Oscillatoria because the species can adapt to a certain temperature.

In contrast to Cyanophyceae, the phytoplankton of the Diatoms class in the Perancak Estuary has more species than Cyanophyceae. The presence of Diatoms is not found in any station. This is probably due to predation by zooplankton and herbivore fish, that Diatoms are a group favored by fish and shrimp larvae.

The diversity index phytoplankton (H') is in the range of 0.00 to 0.10. This value indicates that the phytoplankton diversity in Perancak Estuary is low (figure 3). The value of diversity index is inversely proportional to the index of dominance (D) when the index of diversity and evenness is low. The value of the dominant index is high and vice versa. The evenness index (E) between 0.00 - 0.09 indicates a low uniformity which means the number of species is not evenly distributed or it can be said there is dominance. This can be seen from the high index value of dominance between 0.96 - 1.00 which means there is a type of phytoplankton dominating, namely *Oscillatoria* sp. which can withstand the conditions of the waters of the Perancak Estuary.

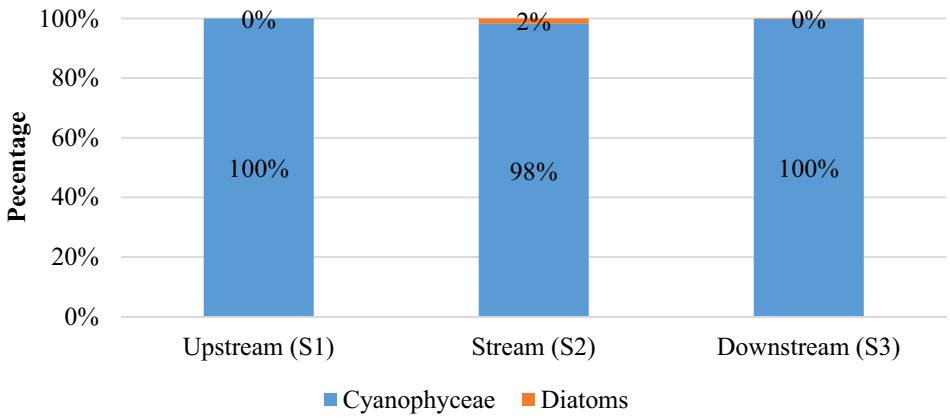

Figure 2. Phytoplankton composition in Perancak Estuary.

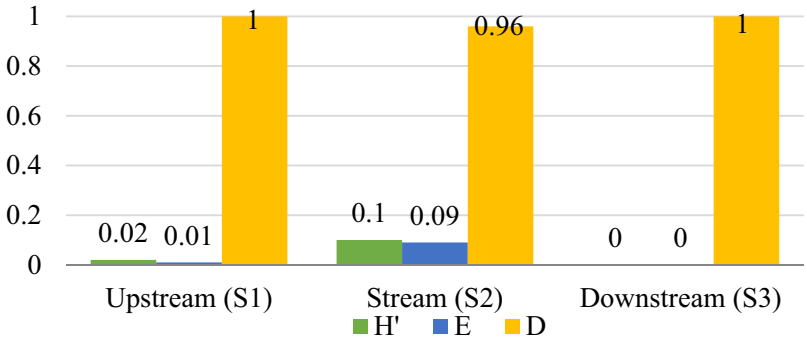

Figure 3. Ecological index of phytoplankton in Perancak Estuary.

3.3 Zooplankton abundance and distribution

The upstream (S1) has the highest composition and abundance of zooplankton in the Perancak Estuary. The abundance of zooplankton in the upstream reached 57.300 and/m3. The high abundance of zooplankton in the upstream is due to the presence of Phylodina sp. (Rotifera) is 33,900 and/m3. According to [24]. Phylodina sp. found in waters with high organic matter and mossy. This is by the condition of upstream containing organic material from household waste. farm activities and agriculture of the surrounding population. Analogous to phytoplankton abundance. the highest abundance of zooplankton in the upstream. The abundance of zooplankton depends on the abundance of phytoplankton.

Zooplankton affects the potential for the emergence and distribution of pelagic fish, in which almost all pelagic fish are high market demand. Fish communities typically develop well in areas where planktonic

organisms are in high density because the grown fish has to make sure its juvenile can get enough food. Also. Zooplankton can be used as an indicator of water pollution (table 3).

Table 3. The abundance of zooplankton in Perancak Estuary.

No.	Class of Zooplankton	Density (ind/m^3)		
		Upstream (S1)	Stream (S2)	Downstream (S3)
	Bivalvia			
1	*Mytilus* sp.	9,300	-	-
	Ciliata			
2	*Undella* sp.	300	-	-
	Crustacea			
3	*Acartia* sp.	300	2,700	-
4	*Calanus* sp.	300	300	-
5	*Eurytemora* sp.	-	600	-
6	*Temora* sp.	300	-	-
	Cephalochordata			
7	*Amphioxides* sp.	7,800	300	-
	Gastropoda			
8	*Limacina* sp.	900	-	-
	Holothuroidea			
9	*Pelagothuria* sp.	300	-	-
	Rotifera			
10	*Brachionus* sp.	2,100	600	-
11	*Keratella* sp.	-	300	-
12	*Phylodina* sp.	33,900	300	-
	Polychaeta			
13	*Harmathoa* sp.	1.500	900	-
	Scaphopoda			
14	*Littorina* sp.	300	-	-
	Density (ind/m^3)	57,300	6,000	-

Rotifera is commonly found in freshwater ecosystems and plays an important role in the food chain as a natural food of shrimp and fish larvae. This high abundance of Rotifera can be attributed to the high abundance of phytoplankton in the upstream. Rotifers are food for larger animals such as worms and crustaceans. The crustacean was dominated in the stream (S2). The role of Crustaceans in a pelagic ecosystem is very important from a trophic point of view as a bridge between primary and secondary marine producers because the crustacean growth rate is relatively fast so that its abundance is higher than other zooplankton classes [25]. Figure 4 shows that crustacean abundance at station S2 is 60%.

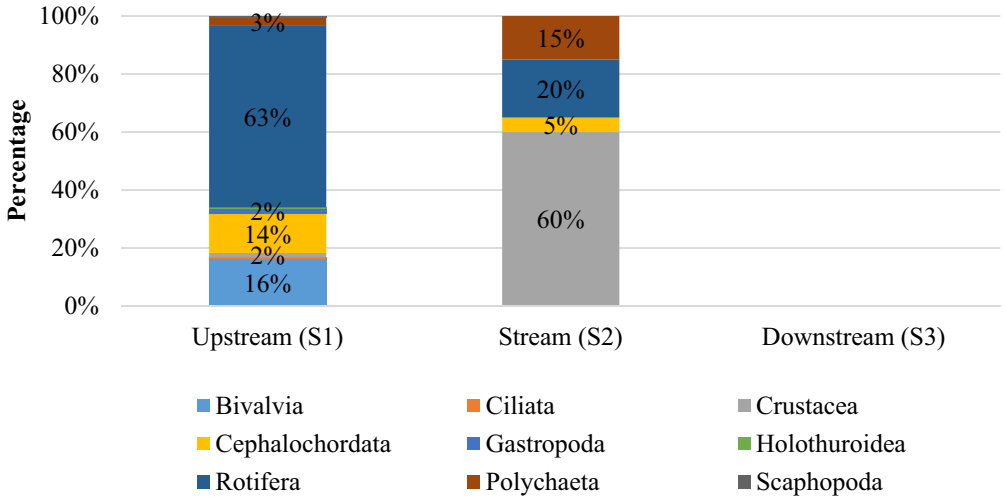

Figure 4. Zooplankton composition in Perancak Estuary.

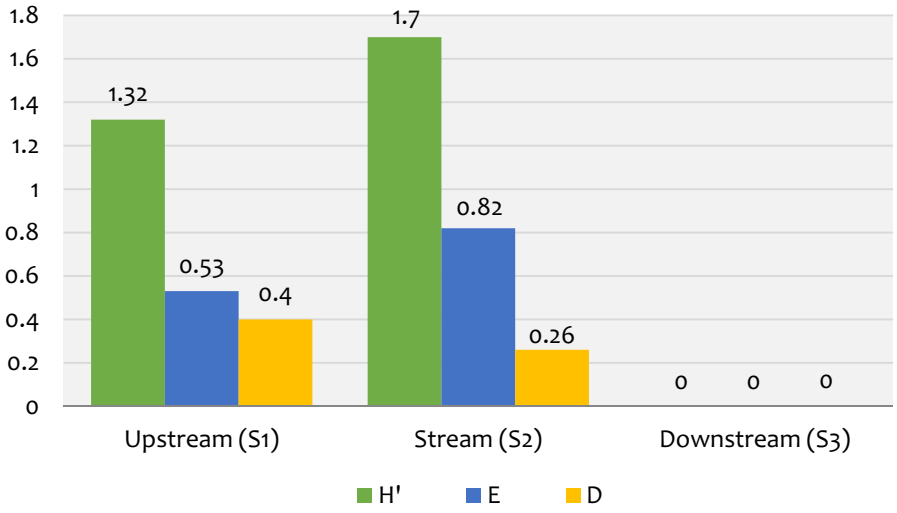

Figure 5. Ecological index of zooplankton in Perancak Estuary.

The diversity index of zooplankton (H') in the Perancak Estuary belongs to the medium diversity class in the range of 1.32 to 1.7. While for the evenness index (E) obtained range 0.53-0.82 shows high uniformity which means the number of inter-species is evenly or can be said there is no dominance. This can be seen from the low dominance index (D) value between 0.26 - 0.4 which means there are no species of zooplankton dominating in Perancak Estuary (figure 5).

4. Conclusion

The results showed that the type and abundance of plankton were quite varied with the number of species found as many as six types of phytoplankton and 14 types of zooplankton. The ecological index shows that the diversity of phytoplankton and zooplankton in the Perancak Estuary is low and there are no dominating species with stable uniformity and tend to be evenly distributed. Plankton abundance in Perancak area can

be used as an indicator of aquatic ecology. Physico-chemical water quality in Perancak Perancak Estuary shows the normal range for the life of plankton and other aquatic biotas.

References

[1] Nybakken J W and Eidman H M 1992 *Biologi Laut: Suatu Pendekatan Ekologis* PT Gramedia Pustaka Utama
[2] Yuliana 2009 Komposisi dan Kelimpahan Plankton di Kepulauan Guraici Kabupaten Halmahera Selatan Maluku Utara *Lutjanus* **14**(1): 49–53
[3] Newell G E and Newell R C 1977 Marine Plankton Hutchinson
[4] Reynolds C S 2006 *The Ecology of Phytoplankton* Cambridge University Press
[5] Follows M J. S Dutkiewicz Montoya J M. Cermeno P. Loreau M. and Vallina S M 2014 Global Relationship between Phytoplankton *Nature Communications* 5 Nature Publishing Group: 1–10 doi:10.1038/ncomms5299
[6] Rochelle-Newall E J. Chu V T. Pringault O. Amouroux D. Arfi R. Bettarel Y and T Bouvier 2011 Phytoplankton Distribution and Productivity in a Highly Turbid. Tropical Coastal System (Bach Dang Estuary. Vietnam) *Marine Pollution Bulletin* **62**(11): 2317–29 doi:10.1016/ j.marpolbul.2011.08.044
[7] Cloern J E 1991 Tidal Stirring and Phytoplankton Bloom Dynamics in an Estuary *Journal of Marine Research* **49**(1) Sears Foundation for Marine Research 203–21
[8] Eaton A D. Lenore S C. Eugene W R. Greenberg A E and MAH Franson 2005 APHA: Standard Methods for the Examination of Water and Wastewater *Centennial Edition APHA. AWWA. WEF. Washington. DC*
[9] Yamaji I 1976 *Illustration Of The Marine Plankton Of Japan* Hoikusha Publishing Co. LTD Japan
[10] Shannon C E and Weaver W 1963 *The mathematical theory of communication* University of Illinois Press p 125
[11] Odum E P 1971 Fundamental of Ecology. WB Saunders *Company Toronto*
[12] Cervetto G. Raymond G and Marc P 1999 Influence of Salinity on the Distribution of Acartia tonsa (Copepoda. Calanoida) *Journal of Experimental Marine Biology and Ecology* **239**(1): 33–45 doi:10.1016/S0022-0981(99)00023-4
[13] Lawrence D. Valiela I and Tomasky G 2004 Estuarine Calanoid Copepod Abundance about Season. Salinity. and Land-Derived Nitrogen Loading. Waquoit Bay. MA *Estuarine. Coastal and Shelf Science* **61**(3): 547–57 doi:10.1016/j.ecss.2004.06.018
[14] Devreker D. Sami S. Gesche W. Joëlle Forget-Leray and François L 2009 Effects of Salinity. Temperature and Individual Variability on the Reproduction of Eurytemora Affinis (Copepoda; Calanoida) from the Seine Estuary A Laboratory Study *Journal of Experimental Marine Biology and Ecology* **368**(2) Elsevier B V: 113–23. doi:10.1016/j.jembe.2008.10.015
[15] Paturej E and Gutkowska A 2015 The Effect of Salinity Levels on the Structure of Zooplankton Communities *Arch. Biol. Sci.* Belgrade **67**(2) 483-492 DOI: 10.2298/ABS140910012P
[16] Boyd C E and Craig S T 2012 *Pond Aquaculture Water Quality Management* Springer Science & Business Media
[17] Schindler D W 1974 Eutrophication and Recovery in Experimental Lakes: Implications for Lake Management *Science* **184**(4139): 897–99 doi:10.1126/science.184.4139.897
[18] Henderson S B.. and Markland H R 1987 *Decaying Lakes The Origins and Control of Cultural Eutrophication* New York: John Willey & Son
[19] Jin L. Wu H.. and Chen M 2011 Effect of Nitrogen and Phosphorus on Phytoplankton Composition and Biomass in 15 Subtropical. Urban Shallow Lakes in Wuhan. China *Limnologica* **41**(2001) 48-56
[20] Kennish M J 1990 Ecology of Estuaries Vol **II** Biological Aspect CRC Press Boston

[21] Soedibjo B S 2007 *Pengaruh Faktor Lingkungan Terhadap Distribusi Spasial Komunitas Zooplankton Di Teluk Klabat. Perairan Bangka Belitung*. Oseanologi dan Limnologi di Indonesia Volume **33**(1): 47-63
[22] Mason C F 1991 Biology of Freshwater Pollution. Longman Scientific and Technical New York. John Wiley & Sons Inc.
[23] Bold 1985 Introduction to the Algae Structure and Reproduction 2nd Ed. Prentice Hall. Inc. Englewood Cliffs *In*: Prihantini 2008 *Biodiversitas Cyanobacteria Dari Beberapa Situ/Danau di Kawasan Jakarta-Depok-Bogor Indonesia* Makara Sains Volume **12**(1): 44-54
[24] Hochberg 2000. *Functional morphology of the muscle in Phylodina sp. (Rotifera: Bdelloidea)* Hydrobiologia Volume **432**: 57-64
[25] Razouls C. De Bovée F. Kouwenberg J and Desreumaux N 2005 Diversity and Geographic Distribution of Marine Planktonic Copepods *Available from WWW:< Http://copepodes. Obs-Banyuls. Fr/en>[cited 2008-08-10]*