The Existence of Phytoplankton and Zooplankton During Solar Eclipse in A Single Spot of Pramuka Island Waters, Seribu Islands

NTM Pratiwi*, RZulmi, DMulyawati, and GSASulaiman
Department of Aquatic Resources Management,
Faculty of Fisheries and Marine Sciences, Bogor Agricultural University
Jl. AgatisKampus, Dramaga, Bogor 16680

E-mail: niken_tmpratiwi@yahoo.com

Abstract. The observation of phytoplankton and zooplankton in Karang Lebar Lagoon during solar eclipse periods was held in order to understand the existence of the community in this special and unusual phenomenon of nature. There were 13 temporally sampling to take plankton and water quality samples, one day before (twice), during (eight times), and one day after the eclipse (three times). The results show that the number of taxa and abundance of plankton during solar eclipse for both phytoplankton and zooplankton were lower than the daylight normal condition. Furthermore, the highest value of Shannon diversity and Evenness index, and also the succession rate of phytoplankton species were reached just after the solar eclipse over. Most of this pattern was followed by zooplankton species at the next sampling periods. As a whole, there were different existence pattern of plankton performs between solar eclipse period and normal condition.

1. Introduction
The solar eclipse being a rare natural phenomenon gives an opportunity to investigate how the ionising radiations react to the material surface of the earth due to the fast solar radiation changes. A huge quantity of shorter wavelength radiations are expected to reach the earth’s surface during solar eclipse since the disturbance of the heat balance along the supersonic travel of the trajectory of the Moon’s shadow could generate eclipse induced gravity waves [1].

Solar eclipse, especially total solar eclipse, is one of long periodical phenomenon, therefore there are lack information about relationship between the phenomenon and its effect, relatively, especially related to the aquatic organisms. Solar eclipse in the area study was a total eclipse with 350 years period. However, another type of solar eclipse in this research location had occurred in 1901,1926,1929,1934,1962,1983, 1984, 1988, and 1995. The total eclipse made a rapid change of light intensity, that presumably leads change of another environment condition [2].

The environmental effects of a solar eclipse have been mainly focused on meteorological parameters [1], photochemistry [3], boundary layer physics [4], total columnar ozone [5], gravity waves [6], ionospheric parameters [7] and also plants [8] and animals [9]. Temperature, relative humidity, wind and cloudiness are among the most common meteorological parameters measured in experimental campaigns during solar eclipses [3]. Radiations at shorter wavelengths are generally influenced more by the eclipse. Various solar eclipse effects on plants mainly related to the abrupt solar light “switch off” such as transient aberrations in
the chromosomal structure of root meristems and a delaying seed germination, effects on photosynthesis and evapotranspiration of crop plants, etc. [3].

Light effects on the photochemical phase of photosynthesis may be responsible for the observed depression in photosynthetic rates. Field studies addressing the migratory responses of marine zooplankton (microzooplankton (ciliates), and meso-zooplankton) due to the rapid changes in underwater light intensity were also performed. The light intensity attenuation was simulated with the use of accurate underwater radiative transfer modelling techniques. Ciliates, responded to the rapid decrease in light intensity during the eclipse adopting night-time behaviour. From the meso-zooplankton assemblage, various vertical migratory behaviours were adopted by different species [4]. The aim of the observation was to study the existence of phytoplankton and zooplankton in Secchi depth layer of Karang Lebar Lagoon during solar eclipse.

2. Materials and Methods
The observation was carried out at wide coral reefs lagoon surround Karang Lebar Lagoon, in the area of Seribu (Thousand) Islands, Jakarta (Figure 1). The sampling site was restricted and protected from anthropogenic activities in order to get clear information about the respond of plankton towards solar eclipse phenomenon.

Vertical sampling of plankton was done compositely from Secchi depth to water surface. There were 13 temporally sampling to take plankton and water quality samples; one day before (twice: 12.00 and 16.00 o’clock), during (eight times: 06.00, 08.00, 10.00, 12.00, 14.00, 16.00, 18.00, and 20.00 o’clock), and one day after the eclipse (three times: 06.30, 12.00, and 16.30 o’clock). The observation of water quality comprised of temperature, pH, salinity, and nutrients that were analyzed in the Water Quality Laboratory of Aquatic Productivity and Environment Division, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University.

Figure 1. Research location and sampling site at Karang Lebar Lagoon
2.1. Sample collection
The plankton samples were collected with plankton net that drawn vertically (hauling) from Secchi depth to water surface. The samples were preserved with 1% Lugol’s solution and identified using plankton identification guide [5], [6], and [7]. The counting of plankton was based on SRC (Sedgwick Rafter Counting cell) observation [8]. The specimens were documented in photograph that was supported by trinocular microscope Zeiss Primo Star with camera and software AxioVision Rel 4.8.

In situ water quality measurements were carried out for temperature, dissolved oxygen/DO, salinity, pH, water depth, water transparency, and light intensity. Nutrients that consist of nitrate-N, nitrite-N, ammonia-N, ammonium-N, and orthophosphate were analyzed in laboratory [8].

2.2. Data analysis
The diversity of plankton along the solar eclipse were determined as Shannon-Wiener diversity index \((H')\), Evenness index (E), and Simpson diversity or Dominance index \((C)\) [9]. Those indices show the stability of plankton community in the circumstantial condition.

The data analysis was used to determine succession of plankton during unusual and rapid change of light intensity. Summed Difference Index or SDI indicated the rate of succession [10]. The index was formulated as follows.

Summed difference index \((SDI; \sigma_s)\) is a formulation to calculate the movement, change, or succession rate of plankton. SDI is formulated as follows.

\[
\sigma_s = \sum_i \left| \frac{d[b_i(t)/B(t)]}{dt} \right|
\]

The formulation for specific time interval is:

\[
\sigma_s = \sum_i \left| \frac{[b_i(t_1)/B(t_1)]-[b_i(t_2)/B(t_2)]]}{t_2-t_1} \right|
\]

with:

\(b_i(t)\) : Species density of each observed time
\(B(t)\): Total density of each observed time.

The difference existance pattern of plankton performances along the solar eclipse towards the other periods were analyzed by Student t-test [11]

\[
t = \frac{x - \mu_0}{s/\sqrt{n}}
\]

Information:

t: t test
\(x\): Average sample
\(\mu_0\): Average Average specific or particular (which becomes the comparison)
\(s\): standard deviation of the sample
\(n\): number of samples.

3. Results and Discussion
The results showed that the abundance and number of species of phyto plankton were relatively low during the time of solar eclipse. The increasing was shown at 12.00 o’clock of the solar eclipse day, and the extremely spike in abundance value was shown at 12.00 o’clock of the next day. The fluctuation pattern was quite similar between abundance and number of species (Figure 2a and 2b). Bacillariophyceae was the dominance group, mostly, both in abundance and the number of species.
The different condition was shown at noon and afternoon of the next day that the Cyanophyceae had higher density than Bacilloriaphyceae.

Figure 2. Composition of phytoplankton as abundance (a) and number of species in period of solar eclipse (b)

The amount of light (or solar radiation) strongly affects both the amount and rate of photosynthesis. Thus the photosynthesis occurring in a water sample is proportional to the light intensity; photosynthesis increases with the increasing light intensity up to some maximal value (Pmax). At still higher light intensities, there may be a significant decrease in photosynthesis (called photoinhibition) that is caused by a number of physiological reactions such as shrinkage of chloroplasts in bright light [12].

The drop in solar irradiance and the increase in mesophyll CO2-concentration during the eclipse did not induce stomatal closure thus not blocking CO2 uptake by plants. Light effects on the photochemical phase of photosynthesis may be responsible for the observed depression in photosynthetic rates [13].

The zooplankton community also showed a unique pattern. There were low density and species number during solar eclipse, but with different group of dominance. The Crustacea was always in high level of abundance during the observation. But the Protozoan that usually had high number of species was replaced by Crustacea at the time of solar eclipse (Figure 3a and 3b).
Animals alter their behaviour [14] and some planktonic Crustacea are vertically redistributed [15] [16]. The evidence suggests that certain species of epipelagic oceanic copepods and euphausiaceans in the Gulf of Mexico responded to the noontime total solar eclipse of March 1970 by migrating to the surface [17].

Light intensity as well as other environmental factors such as temperature, hydrostatic pressure, and pH can affect the direction and intensity of swimming of zooplankters. The vertical migratory performance can be most easily interpreted by the hypothesis zooplankters were responding exclusively to concurrent light intensity [18].

Field studies addressing the migratory responses of marine zooplankton (microzooplankton (ciliates), and meso-zooplankton) due to the rapid changes in underwater light intensity were also performed. The light intensity attenuation was simulated with the use of accurate underwater radiative transfer modelling techniques. Ciliates, responded to the rapid decrease in light intensity during the eclipse adopting night-time behaviour. From the meso-zooplankton assemblage, various vertical migratory behaviours were adopted by different species [1].

The community structure of phytoplankton indicated that the diversity was low at the beginning of eclipse phenomenon, and increased to moderate at the end of the day. The unique things were appeared at the following day that there were shown declining values of diversity and Evennes index to minimum level. Meanwhile, the opposite thing was occured in dominance index that showed maximum level. The zooplankton showed a different condition. All diversity indices were relatively constant (Figure 4a and 4b).
It was clearly shown that the pattern of diversity was in line with the Eveness value, along the observation. Furthermore, the dominance value was in contrast with the value of those two indices. It means that the relationship between ecological index of the plankton community structure was well illustrated.

The SDI showed the rate of succession or the change of species in certain time interval. The highest rate of plankton occurred in the time of solar eclipse. From Figure 5a and 5b, it is shown that zooplankton community was changed earlier than phytoplankton community.

**Figure 4.** Diversity indices of phytoplankton (a) and zooplankton (b) in time of solar eclipse phenomenon
There were some descriptions of the existence of plankton community, such as density, number of species or richness, Shannon diversity index, evenness index, and Simpson’s dominance index, in time of solar eclipse phenomenon. The pattern of phytoplankton density was relatively different from the zooplankton.

The density and number of species of phytoplankton along the solar eclipse were significantly different ($p<0.05$) from the density at the same time of one day before and after solar eclipse, but quite similar ($p>0.05$) to the density of dark time, of one day after eclipse. Meanwhile, the density of zooplankton was only significantly different ($p<0.05$) from the density at the same time of one day after solar eclipse.

There were not any significantly differences ($p>0.05$) among all of indices for the phytoplankton community. On the contrary, and the interestingly was shown by the Shannon diversity and the Simpson’s dominance indices of zooplankton that significantly different ($p<0.05$) from the condition along the eclipse with the same time of one day after solar eclipse and to the condition of dark time, of one day after eclipse.

As a whole, it was shown that the existence of phytoplankton along the solar eclipse very similar to those of the dark periods. This was different with the zooplankton that showed relatively similar performance as daylight existence, along the solar eclipse, and showed a different performance at dark situation. It means that there were different performance pattern of phytoplankton and zooplankton community in responding the solar eclipse phenomenon.

In essence, a high change of intensity produced an alteration of photonegative and photopositive phases and the net result had relatively little effect on the depth at which the animal was located. When changes in light intensity were slow. However, the animals simply followed the movement of the original optimum zone [12].

The environmental condition was represented by the measurement result of in situ observation and nutrient analysis as laid in Table 1 and 2. It was indicated that the most different condition at the same time of observation was the light intensity.
There was only 18.25% of light intensity from the normal condition at 06.00 before it became totally dark at 07.00. It was relatively similar with another observation that the light intensity of eclipse day was 1002 lux with the minimum value of the eclipse day as 10 lux [3].

The other water quality parameter that influenced by solar eclipse was pH. As seen in Table 1, the pH condition during eclipse period to the midday of 9 March was decreased. The gamma rays are reaching the earth’s surface during eclipse since the pH value of seawater is reduced when exposed to solar radiation because gamma irradiation reduces the pH value of water [1].

Table 1 Water quality in time of solar eclipse at single spot of Pramuka Island

| Parameter      | Units | 8 March   | 9 March   | 10 March |
|----------------|-------|-----------|-----------|----------|
|                |       | 12.00     | 16.00     | 06.00    | 08.00    | 10.00    | 12.00    | 14.00    | 16.00    | 18.00    | 20.00    | 06.00    | 12.00    | 16.00    |
| Depth          | m     | 11        | 11        | 11       | 11       | 11       | 11       | 11       | 11       | 11       | 11       | 11       | 11       | 11       |
| Transparency   | m     | 6         | 6         | 6        | 6        | 6        | 6        | 6        | 6        | 6        | 6        | 6        | 6        | 6        |
| DO             | mg/L  | 6.9       | 7.5       | 3.2      | 5.2      | 6.1      | 7.4      | 9.1      | 8.8      | 8        | 7.6      | 3.6      | 6.3      | 7.6      |
| Temperature    | °C    | 29.7      | 30.7      | 28.6     | 29.4     | 29.8     | 29.9     | 31.6     | 32.6     | 32.4     | 31.3     | 29.2     | 31.4     | 33.1     |
| pH             | -     | 8.06      | 8.03      | 7.44     | 7.86     | 7.92     | 7.96     | 8.1      | 8.17     | 8.22     | 8.11     | 7.63     | 8.11     | 8.3      |
| Salinity       | ppt   | 29.8      | 29.8      | 29.8     | 30       | 30       | 29.9     | 30.1     | 30.1     | 30.2     | 30.2     | 30.2     | 30.2     | 30.3     |
| Conductivity   | μM/Hos/cm | 46200  | 46200  | 46100  | 46400  | 46400  | 46300  | 46600  | 46700  | 46800  | 46800  | 46600  | 46700  | 46900  |
| TDS            | g/L   | 23.56     | 23.57     | 23.5     | 23.67    | 23.6    | 23.77   | 23.83   | 23.87   | 23.87   | 23.87   | 23.78   | 23.83   | 23.92   |
| Light intensity| lux   | 54700     | 48473     | 1248    | 26220   | 39600  | 52980  | 102060 | 65900  | 951     | 6838   | 85920  | 40800  |

There was not any significance difference condition of nutrients, before, during, and after solar eclipse occurred. As a whole, all of nutrients were relatively adequate for the living and growth of phytoplankton.

Table 2 Water nutrients in time of solar eclipse at single spot of Pramuka Island

| Parameters                        | Units | 8 March | 9 March | 10 March |
|-----------------------------------|-------|---------|---------|----------|
| Ammonia (NH₃-N)                   | mg/L  | 0.082   | 0.050   | 0.102    |
| Nitrate (NO₃-N)                   | mg/L  | 0.056   | 0.046   | 0.062    |
| Nitrite (NO₂-N)                   | mg/L  | 0.002   | 0.002   | 0.002    |
| Orthophosphate (PO₄-P)            | mg/L  | 0.010   | 0.011   | 0.011    |

The results showed that the number of taxa and abundance of plankton during solar eclipse for both phytoplankton and zooplankton were lower than the daylight normal condition. Furthermore, the highest value of Shannon diversity and Evenness index, and also the succession rate of phytoplankton species were reached just after the solar eclipse over. Most of this pattern was followed by zooplankton species at the next sampling periods.

4. Conclusion
As a whole, there were different pattern of richness, diversity, and abundance of plankton between solar eclipse period and normal condition.

Reference
[1] Kumar SS, R Rengaiyan. 2011. Influence of solar eclipse on seawater. *Natural Science.* 3(1): 69-74.
[2] Littmann, Espenak, Willcox. 2008. Totality: Eclipses of The Sun.Oxford University Press.
3. Sambandan K, DeviKS, KumarSS, NancharaiahM, DhatchanamoorthyN. 2012. Effects of solar eclipse on photosynthesis of Portulacaoleracea and Phyla nodiflora in coastal wild conditions. *Journal of Phytoology*. 4(2): 34-40.

4. Economou G, ChristouED, GiannakourouA, GerasopoulosE, GeorgopoulosD, KotoulasV, LyraD, TsakalisN, TzortziouM, VahamidisP, PapanthiassouE, KaramanosA. 2008. Eclipse effects on field crops and marine zooplankton: the 29 March 2006 total solar eclipse. *Atmospheric Chemistryand Physics*. 8: 4665-4676.

5. Davis CC. 1955. *The Marine and Freshwater Plankton*. Michigan State University Press. USA.

6. Yamaji IE. 1979. *Illustration of The Marine Plankton of Japan*. Hoikusha Publishing Co. Osaka.

7. Tomas CR. 1977. *Identifying Marine Phytoplankton*. Academic Press. California. USA.

8. APHA, AWWA, WEF. 2012. *Standard Methods for examination of water and wastewater*. 22nd ed. Washington. American Public Health Association.

9. Krebs CJ. 1972. *Ecology: The Scientific Study of the Interactions that Determine the Distribution and Abundance of Organisms*. Harper & Row Publisher. New York.

10. LewisWMJr. 1978. Analysis Of Succession In A Tropical Phytoplankton Community and A New Measure of Succession Rate. *The American Naturalist*. 112(984): 401-414.

11. Walpole, R.E. dan R.H. Myers. 1995. Ilmu Peluang dan Statistika untuk Insinyur dan Ilmuwan. Edisi keempat. Penerbit ITB. Bandung.

12. Lalli M, XR Parsons. 2006. *Biological Oceanography: an Introduction*. - 2nd ed. Chapter 3: Radiation and Photosynthesis. Elsevier Butterworth-Heinemann Linacre House, Jordan Hill, Oxford.

13. SkudBE. 1967.Responses of Marine Organisms during The Solar Eclipse of July 1963. *US Fish and Wildlife Service Fishery Bulletin*. 66: 259-271.

14. Jennings S, Bustamante R, Collins HK, Mallinson J. 1998. Reef fish behaviour during a total solar eclipse at Pinta Island, Galapagos, *Journal of Fish Biology*. 53: 683-686.

15. VecchioneM, MaplesRS, Donahoe R. 1987.Changes in chlorophyll a concentrations in a shallow water column during a solar eclipse. *Smithsonian Contribution to the Marine Sciences*. 29: 37-44.

16. Giroud C, BalvayG. 1999. The solar eclipse and the migration of some planktonic crustacea in Lake Geneva. *Archaeological Science*. 52: 199-208.

17. Bright T, F Ferrari, D Martin. 1972. Effects of a total solar eclipse on the vertical distribution of certain oceanic zooplankters. *Limnology and Oceanography*. 17(2): 296-301.

18. Enright JT. 1967. Vertical Diurnal Migration and Endogenous Rhythmicity. *The Journal of Science*. 157: 937-943.