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PHYTOPLANKTON AND ZOOPLANKTON DISTRIBUTION PATTERNS AT DIFFERENT TIMES AND DEPTHS IN FISHING AREA OF KUPANG BAY SEA WATERS

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ABSTRACT

This study was to analyze the distribution patterns of phytoplankton and zooplankton at different times and depths in the fishing area of Kupang Bay. The method used in this study was the trap method for plankton sampling using plankton nets and the Swdwich Rafer Counting Cell (SRCC) method to identify and enumerate plankton types. The results of the study showed that the density of phytoplankton and zooplankton at different times and depths in different fishing locations was different, namely the density of phytoplankton was higher than zooplankton. On a full moon, the density of phytoplankton was higher than zooplankton and in the the middle part, the density of phytoplankton and zooplankton were higher than the surface and bottom. The distribution pattern of phytoplankton and zooplankton at different times and depths was a uniform and regular distribution. Environmental conditions at the fishing area of Kupang Bay were classified as good or suitable for the survival or growth of plankton. It is necessary to continue preserve the coastal and marine environment of Kupang Bay to maintain the potential of the area as a fishing area for local fishermen.

Keywords: phytoplankton, zooplankton, density, full moon, crescent moon, different depths

INTRODUCTION

Plankton in the ocean are an important food source for many small and large aquatic organisms. Marine plankton include bacteria, archaea, algae, protozoa, microscopic fungi (Lawton, Graham 2024) and drifting or floating animals that inhabit the salt water of the ocean and the brackish water of estuaries. Phytoplankton are the autotrophic component of the plankton community and an essential part of marine and freshwater ecosystems. Phytoplankton obtain energy through photosynthesis. Phytoplankton must obtain light from the sun, so they live in the bright surface layer of oceans and lakes. Phytoplankton form the base of marine and freshwater food webs and play a vital role in the global carbon cycle. Phytoplankton are extremely diverse, ranging from photosynthetic bacteria to plant-like algae to armored coccolithophores. Important phytoplankton groups include diatoms, cyanobacteria and dinoflagellates, although many other groups are represented (Pierella et al. 2020). Zooplankton are the animal components of the planktonic community that must eat other organisms to thrive. Most zooplankton are microscopic, but some (such as jellyfish) are macroscopic (Sardet, Christian 2015). Phytoplankton in waters are the main source in the food chain, which contributes to fishery resources and is responsible for the formation of biological communities and the regulation of food webs in waters (Vajravelu et al. 2018). Zooplankton mainly consume primary producers and are the main food source for tertiary consumers (Ningsih et al. 2020). The abundance of phytoplankton can affect the abundance of zooplankton, because zooplankton are consumers of phytoplankton (Piontkovski et al. 2014). The abundance of phytoplankton and zooplankton behavior are interrelated. This interaction is an interaction between prey and predator.

The study of phytoplankton and zooplankton distribution is important because it is related or very useful for predicting commercial fish populations (Hardy 1939). The distribution of phytoplankton in waters is not homogeneous or even. The difference in density between one water area and another in the sea can range from 10-100 km. This means that after 10 km of relatively homogeneous phytoplankton, outside that area different phytoplankton conditions will be found (Basmi 1995). According to Basmi (1999), generally the abundance of zooplankton depends on the abundance of phytoplankton, but zooplankton production is slower than phytoplankton production, so that the peak of zooplankton production always occurs behind the peak of phytoplankton. The abundant concentration of phytoplankton and zooplankton in an area is rarely found at the same time. There are two hypotheses that explain this, first, zooplankton will prey on phytoplankton so that the phytoplankton population will decrease and second, that zooplankton avoid areas rich in phytoplankton, namely they are outside the area. However, if we compare the relative abundance of phytoplankton and zooplankton in the sea, we will not always find the conditions described above (Basmi 1998). Thus, further research that is repeated in various places and times is still relevant to be carried out, especially on the distribution of phytoplankton and zooplankton. This is related to the physiological activities of plankton such as food assimilation, respiration, movement and reproduction were always influenced by environmental conditions (external factors) such as temperature, light, oxygen content and other physical and chemical conditions (Basmi 1998). The physical condition of the bay waters was influenced by many factors, both external and internal. External influences can come from the open sea that surrounds it, including currents, tides, waves, temperature, salinity or from land in the form of freshwater flows from rivers (Hasanudin 2000). While internal influences include the shape of the bay and the shape of the bottom topography of the bay.

The waters of Kupang Bay are fishing areas for local fishermen. Ninev et al. (1999) state that the amount of fishing in this location was not always stable due to the influence of various factors such as season and fishing time, fishing gear, and fishermen's knowledge/techniques about efficient fishing methods. Generally, fishermen were poorly educated and did not have adequate fishing knowledge. If fishermen have practical knowledge about the influence and position of fish at a certain time and depth, because they follow the movement and distribution of plankton, they will release their nets/hooks at a certain depth and at a certain time. Therefore, this study was to develop information about the distribution of phytoplankton and zooplankton at different times and depths that can be used as a guide for fishing by fishermen.

Generally, the distribution of phytoplankton and zooplankton has been widely studied both in the sea and in lakes in each season but has not been detailed in daily distribution and different depths to determine the tendency of phytoplankton and zooplankton distribution. Is the distribution of phytoplankton the same as the distribution of zooplankton at different times and depths (Sutomo 1995, Andamari 1995, Wardana 1995). In general, research on the distribution of phytoplankton and zooplankton is carried out together, but whether there is a relationship between the distribution of phytoplankton and zooplankton at different times and depths has not been widely revealed. Likewise, the distribution pattern in each water zone and different types of habitats was also not many known, because theoretically zoning, habitat, depth, and time affect the behavior of plankton distribution (Odum 1996, Nybaken 1988). Based on these problems, the main aims of this study were: to investigate whether the density and abundance of phytoplankton and zooplankton are evenly distributed at each time and depth at fishing area in Kupang Bay waters; to find out when and at what depth the density and abundance of phytoplankton and zooplankton are highest; to find out how the distribution pattern of phytoplankton and zooplankton at different times and depths; to investigate whether the distribution pattern of phytoplankton at a certain time and depth was the same as zooplankton, and to find out the condition of the physical and chemical environmental condition of the waters at the fishing area in Kupang Bay waters.

MATERIALS AND METHODS

Data collection

The study was conducted in the waters of Kupang Bay in 2023. The method used in this study was the trap method for plankton sampling and the Swdwich Rafer Counting Cell (SRCC) method to identify and to count plankton types. Sampling was carried out at three different depths (surface, middle and bottom). Sampling time on April 28 to represent the crescent moon and May 12 to represent the full moon, at 6.00 am, 12.00 noon, 6.00 pm, and 00.00 pm. Plankton sampling was carried out using a plankton net with a mesh size of 25 µm. Identification and enumeration of plankton samples were carried out using the sub-sample method on a sedwich reftercell for phytoplankton and a bogorof plate for zooplankton under a stereo microscope with a magnification of 100 times. Identification was carried out based on the books of Davis (1955), Wichstead (1965), Yamaji (1984) and Conaughey and Zootoli (1983). Plankton identification was carried out in the MIPA Undana Biology laboratory while the measurement of physical and chemical parameters of the waters was measured in-situ at each station and depth and some were analyzed in the MIPA Undana Analytical Chemistry laboratory.

Data Analysis

To determine the number of plankton in each unit of volume size, the abundance and density of plankton were calculated. The calculation was conducted by diluting the obtained sample, then the fraction (part) of the sample was calculated. The number of counted results was multiplied by the number of fractions. The calculation of zooplankton was conducted by used the modification of Romimohtarto et al. (2004) method as follows:

$$N = \frac{n}{v} \text{ x a}$$

N = abundance of plankton (number of individuals/I), n = number of individuals in the subsample (subsample/number of zooplankton counted), a = volume of filtered water (100 l). Phytoplankton abundance was calculated by using the formula:

$$N = \frac{n}{m} \text{ x } \frac{s}{a} \text{ x } \frac{1}{v}$$

N = abundance (number of cells per liter), n = number of cells counted in m drops (individual count), m = number of sample drops examined (10 drops), S = sample volume with preservation (50 ml), a = volume of each sample drop (1 ml), V = volume of filtered water (2 liters). The distribution pattern of plankton was analyzed by using the Morista distribution index, which refers to Michael (1995) as follows:

$$IS = n \left[\frac{\sum x^2 - \sum x}{\left(\sum x^2\right) - \sum x} \right]$$

IS = Morisita distribution index, n = Number of sample plots, X = Number of individuals per sample. The criteria for the Morista distribution index were: IS < 1 = Uniform and regular distribution pattern. IS = 1 = Random distribution pattern. IS > 1 = Clumped distribution pattern.

RESULTS AND DISCUSSION

Phytoplankton and Zooplankton Abundance and Distribution Pattern

Based on the identification, of all samples collected about 46 phytoplankton species and 31 zooplankton species were found. The species of phytoplankton were: *Rhizoselenia alata*, *R. polydactila*, *R. styliformis*, *R.hebetata*, *Thallasiosira gravida*, *Th. Alleni*, *Th. Mala*, *Caetoceros trichoceros*, *C. semilis*, *C. debilis*, *C. peruvianus*, *C. sociale*, *Coscinodiscus nobilis*, *C. excentricus*, *Gymnodinium mikimitoi*, *G. sanguineum*, *Lauderia anula*, *L. borealis*, Corethorn, Astrionela, *Aracnodiscus chrenbergi*, *Triceratium farvus*, *Aulacodiscus janischii*, *Triceratium favus*, Pleurosigma, Stauroneis, Peridinium, Pontosphaera, Rhobomonas, Skeletonema sp, *S. costatum*, *Trichodesmium thiebautil*, *Eucapia zodiagus*, *Lioloma elengatum*, *Ceratium tripos*, *C. furea*, *C. focus*, *Nitrichia brebisonii*, Noktiluca sp, Chlorella sp, Spirulina sp, *Folfox aureus*, Navicula sp, Spirogyra, Ulva lactuca, and Tabelaria sp. The species of zooplankton were: *Arcella polypore*, *Amoeba guutulla*, *Euphausia luscens*, *Chyrzoformulina parva*, *Clymmestra rostrata*, *Corethron hystrix*, *Cornutella annulata*, *Cypridina noctiluca*, *Daptomus oregonesis*, *Erythrops abyssorum*, *Euglena accus*, *Euglio polyta*, *Globigerina boludies*, *Gonium formosum*, *Hellioma lactutris*, *Leptomysis mediterranea*, *Lucifer eriensis*, *Lucucutia atlantika*, *Macrostella gracilysis*, *Chaetoceronorus affinis*, *Oithona galdinca*, *Polytoma ufala*, *Starastrum acanasrum*, *S. megacantum*, *Stensor rossali*, *Syanapia nathans*, *Monstrila tenera*, and *Volvox arweus*. Phytoplankton density per lunar phase, sea depth, and sampling time was shown in Table 1 and density of zooplankton per lunar phase, sea depth, and sampling time was shown in Table 2.

Table 1. Phytoplankton density per lunar phase, sea depth, and sampling time

Week/ moon phase	Seabed	Time of sampling	Number of individuals/src (replicates 1-3)	Average (individuals/ ml)	Density (individuals/ L)	Diversity index	Distribution pattern
M.I/ Crescent moon	surface	06.00	96	32	1600	0.35	0.01
		12.00	82	27,3	1,365	0.33	0,01
		18.00	90	30	1500	0.34	0.01
		24.00	98	32.7	1635	0.35	0.01
		x̄	566/4=91.5	30,5	6100/4=1.525	1,37	0.04
	middle	06.00	107	35.7	1785	0.35	0.01
		12.00	92	20.7	1535	0.35	0.01
		18.00	98	32.7	1635	0.35	0.01
		24.00	109	36.3	1815	0.35	0.01
		x̄	406/4=101.5	33.8	6770/4=1693.5	1.38	0.04
	bottom	06.00	90	31.3	1565	0.35	0.01
		12.00	95	29	1450	0.35	0.01
		18.00	87	31.7	1585	0.34	0.01
		24.00	82	31.3	1565	0.34	0.01
		x̄	354/4=92.5	30.8	5900/4=1475	1.38	0.04
		x̄ **M.I**	273.5/3=91.2	30.4	1520	4.13/3=1.38	0.04
		06.00	94	31.3	1656	0.35	0.01

M.I/Full moon	surface	12.00	87	29	1450	0.34	0.01
		18.00	95	31.7	1585	0.35	0.01
		24.00	94	31.3	1565	0.35	0.01
		x̄	570/4=92.5	30.8	6165/4=1.541,1	1.39	0.04
	middle	06.00	108	36	1800	0.35	0.01
		12.00	98	32.7	1635	0.34	0.01
		18.00	102	34	1700	0.34	0.01
		24.00	109	36.3	1.815	0.35	0.01
		x̄	417/4=103.3	34.8	66950/4=1.737	1.38	0.04
	bottom	06.00	90	30	1500	0.35	0.01
		12.00	87	29	1450	0.34	0.01
		18.00	92	30.7	1535	0.35	0.01
		24.00	94	31.3	1565	0.35	0.01
		x̄	367/4=90.8	30.3	6050/4=1512,5	1.39	0.04
		x̄ **M.II**	287.6/3=95.9	32	1600	1.39	0.04

Table 2. Density of zooplankton per lunar phase, sea depth and sampling time.

Week/moon phase	Seabed	Time of sampling	Number of individuals/srcc (replicates 1-3)	Average (individual/ml)	Density (individuals / L)	Diversity index	Distribution pattern
	surface	06.00	44	14.7	735	0.35	0.01
		12.00	35	11.7	585	0.33	0.01

M.I/ Crescent moon		18.00	40	13.3	665	034	0.01
		24.00	45	15.0	750	0.35	0.01
		x̄	264/4=41.0	13.7	2735/4=684	1.37	0.04
	middl e	06.00	46	15.3	765	0.35	0.01
		12.00	37	12.3	615	0.33	0.01
		18.00	42	14.0	700	0.35	0.01
		24.00	44	14.7	735	0.35	0.01
		x̄	169/4=42.25	14.1	2815/4=704	138	0.04
	botto m	06.00	41	13.7	685	0.35	0.01
		12.00	43	14.3	715	0.35	0.01
		18.00	38	12.7	635	0.34	0.01
		24.00	36	12.0	600	0.34	0.01
		x̄	158/4=39.5	13.2	2635/4=658	138	0.04
		x̄ **M.I**	122.75/4=40. 92	13.6	8185/4=682	138	0.04
M.I/Full moo	surfac e	06.00	36	12.3	600	0.35	0.01
		12.00	32	10.32	535	0.34	0.01
		18.00	35	11.0	585	0.35	0.01
		24.00	38	12.7	635	0.35	0.01
		Rata-rata	141/4=35.25	11.3	2355/4=590	139	0.04
	middl e	06.00	40	13.3	665	0.35	0.01
		12.00	34	11.3	565	0.34	0.01
		18.00	36	12.0	600	0.34	0.01
		24.00	38	12.7	635	0.35	0.01

	x̄	148/4=37.0	12.3	2465/4=615	138	0.04
bottom	06.00	42	14.0	700	0.35	0.01
	12.00	38	12.7	635	0.34	0.01
	18.00	40	13.3	665	0.35	0.01
	24.00	41	13.3	685	0.35	0.01
	x̄	161/4=40.25	13.4	2685/4=670	1.39	0.04
	x̄ **M.II**	112.5/3=37.25	12.5	7505/3=625	1.39	0.04

The density of phytoplankton and zooplankton at different times and depths has different values (Tables 1 and 2). Based on the time between the moon phases (crescent moon and the full moon), it was found that the density of phytoplankton on the full moon was higher (1,600 ind/liter) than the crescent moon (1,520 ind/liter). However, on the contrary, the density of zooplankton on the full moon was lower (625 ind/liter) than the crescent moon (682 ind/liter). This confirm that the phototaxis properties of phytoplankton and zooplankton were different. Phytoplankton show positive phototaxis (towards the light) while zooplankton show negative phototaxis properties (away from the light). Although viewed from the interdependent relationship in the food chain, where phytoplankton was the food of zooplankton so that wherever phytoplankton present were always followed by zooplankton, it seem that the influence of phototaxis were stronger than the influence than food. When comparing the density of phytoplankton and zooplankton, both on the crescent moon and the full moon, the density of phytoplankton and zooplankton were always higher in the middle (depth of ± 10 m) compared to surface and bottom. This means that both phytoplankton and zooplankton tend to occupy the middle area because this area still gets light and was a transition between bright and dark areas. This area seem more possible for phytoplankton and zooplankton to adapt if they migrate to brighter or darker areas. Based on daily time, it was found that phytoplankton and zooplankton have higher density at 18:00 and 24:00 compared to 12:00 and 06:00. In general, it was found that both based on time and depth of sampling, the density of phytoplankton was higher than zooplankton. This is thought to be because in aquatic communities, phytoplankton are zooplankton food, so the density of phytoplankton must be higher than zooplankton.

From Tables 1 and 2, it was obtained that the value of the distribution pattern of phytoplankton and zooplankton was 0.04 (IS<1). According to the Morista distribution index, this value was classified as a uniform and regular distribution pattern. Uniform and regular distribution patterns are generally not common in nature. According to Nybaken (1988), in one body of water, both sea and freshwater plankton are generally distributed very unevenly. This uniform and regular distribution pattern is likely influenced by sea conditions, especially the currents and waves that are quite calm when the study was conducted or by the influence of the depth factor of relatively short sampling. From Tables 1 and 2, the diversity values of phytoplankton and zooplankton range from 1 to 3 (1 < H"< 3). Based on the diversity criteria of Fachrul (2007), this value was classified as a moderate diversity. Thus, in general it can be stated that the waters of Kupang Bay are still quite potential to be used for fish farming and fishing efforts.

Environmental Parameters

Environmental factors are limiting factors for plankton populations in marine ecosystems, and are variables that can affect the distribution, diversity, and density of plankton in that ecosystem. The results of environmental factor measurements in the sea waters of Kupang Bay obtained temperatures ranging from 25.1-25.8^{0}C (Table 3). This temperature range was the optimal temperature for the presence and density of plankton in the sea (Kordy 2005). Salinity ranges from 32.0 -32.1 ppm, which is included in the normal seawater salinity category for the survival of plankton (Dahuri 1995). pH ranges from 7.7-7.8. This pH value was included in the productive water conditions for plankton. Likewise, the current strength was quite stable and supports plankton life. Thus, it can be stated that the environmental conditions at the fishing location in the waters of Kupang Bay are classified as good or suitable to ensure the survival or growth of plankton. Environmental conditions that are productive for plankton life in marine ecosystems are temperatures ranging from 20-42^{0}C, salinity 30-40 ppm, and pH 7.5-8.5 (Kordy 2005, Dahuri 1995).

Table 3. Environmental parameter measurements at the fishing location in Kupang Bay waters.

No.	Moon Phase	Environmental Factors				
		Temperature (^{0}C)	Salinity (PPM)	pH	Brightness (m)	Current Strength (m/dt)
1	Crescent Moon	25.80	32.10	7.80	8.30	7.20
2	Full Moon	25.10	32.00	7.70	8.40	7.30

Based on the research results, it can be concluded that: the abundance of phytoplankton and zooplankton at fishing locations in Kupang Bay waters at different times and depths were different, the density of phytoplankton was higher than zooplankton. On a full moon, the density of phytoplankton was higher than zooplankton. The density of phytoplankton and zooplankton in the middle part were higher than those on the surface and r base. The distribution pattern of phytoplankton and zooplankton at different times and depths was a uniform and regular distribution pattern. The distribution pattern of phytoplankton at a certain time and depth is the same as zooplankton. The physical and chemical environmental parameters of Kupang Bay waters were in the range of good values to support the stability of the plankton ecosystem.

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