Analysis of daily dynamics of thermal interaction of temperature and ocean flow in seaweed growth areas

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Analysis of daily dynamics of thermal interaction of temperature and ocean flow in seaweed growth areas

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Abstract. Seaweed (Caulerpa sp) is a marine biota whose growth is influenced by physical parameters. The purpose of this study was to analyze the dynamics of daily temporal changes in seawater temperature at several depth points and variations in the velocity and direction of ocean currents. Make simple mathematical modeling of ocean current velocity and daily dynamics of seawater temperature in the seaweed growth zone and outside the seaweed growth area. Temperature measurements are carried out on 4 depth variations using a current meter when the sun illuminates the ocean. Measurement of the velocity and direction of the current is carried out using a current measuring instrument during the full moon. The Fourier function or periodic function determines mathematical modeling. The results showed that the transect measurement of sea temperature for 4 depth variations experienced changes due to the intensity of solar irradiation. During one cycle, the speed and direction of the ocean currents change periodically, with the average flow velocity in the seaweed zone being 7.4 m/min and outside the Lahe region being 18.75 m/min directly to the southwest at seawater flows at high tide and northeast experiencing low tide. The daily temporal change in ocean current velocity for each measurement transect shows the same shape which is modeled according to the Fourier function.

1. Introduction

The Seaweed is an important marine natural resource and can be called a futuristic promised plant. This plant has become a source of food, feed, and medicine, industrial agar production, alginate, and fertilizer [1]. Seaweed from the coast is high in nutrients and various bioactive compounds which have various beneficialroles such as antioxidant properties [2]. Seaweed is one of the cultivated fishery commodities that have the potential to support the welfare of the community so that it needs to be cultivated quickly and precisely to serve production demands in quantity, quality, and continuity with the optimization of resources and applied science [1]. Seaweed also has the ability to absorb and store carbon dioxide which is extraordinary 5 times more than most land plants [2]. According to Neksidin seaweed is a biological resource that has been utilized by the Indonesian people as a livelihood, and in several areas, it is the main livelihood [3]. Seaweed has high economicvalue, is easy to cultivate, and has low production costs. Therefore, seaweed is a plant that has a strategic role in human survival. The potential of seaweed (algae) in Indonesianwaters can be seen from the potential for seaweed cultivation in all provinces in Indonesia.

Several districts in North Sulawesi have seaweed development centers, but the seaweed in Batunderang Village, Sangihe District, North Sulawesi, grows naturally.

On the coast of Batunderang Village or on the lower part of the land there are mangroves whose existence can function as an ecological feature of seaweed. Mangrovescan control waste and garbage from the land for the preservation of seaweed. Seaweed that grows naturally is green (Caulerpa sp). Seaweed is a simple type of plant because it cannot be distinguished between actual roots, stems, and leaves [4]. Seaweed grows at low tide and generally grows (attaches) to solid substrates such as dead coral, rocks, or tree trunks [5]. In general, resources that still rely on natural products have many obstacles, including low production due to seasonal dependence. This results in unsustainable production and seriously threatens the sustainability of this crop. Certain biota, including seaweed, has a certain temperature range that ensures the fertility and productivity of the seaweed. Seaweed is affected by various environmental conditions such as high and low temperatures [6]. Temperature is an important factor in regulating life processes and the distribution of organisms in waters including seaweed. Therefore, seawater temperature data can be important basic data for seaweed cultivation. Plants use sunlight as their main energy source to carry out a process called photosynthesis. Photosynthetic organisms in the sea such as algae and phytoplankton must live in well-litwater surfaces called the euphotic zone. In clear tropical waters, the euphotic zone can extend to a depth of 80 meters. Sunlight does not penetrate very deeply near the poles, soin this area, the euphotic zone may be less than 10 m. Turbid and muddy waters may haveeuphotic zones only a few centimeters deep. Figure 1, The sunlight that penetrates the water will be attenuated so that the intensity of the sunlight will decrease according to thedepth of the water.

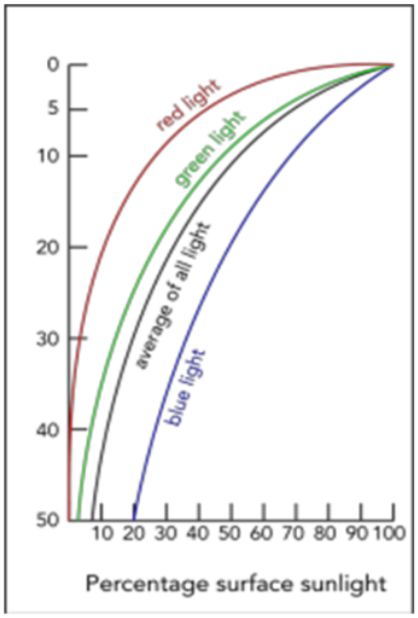

Figure 1. The intensity of sunlight decreases rapidlywith depth. Image by Byron Inouye.

At the first 10 m depth, water absorbs more than 50 percent of visible light and in clear tropical water, about 1 percent of visible light penetrates up to 100 m and is mostly blue light. The decrease in light intensity occurs after the material moved gradually. Lee et al explained that about 10% of UVA radiation can penetrate the ocean depths of 5-10 m [7].

When the seawater temperature is higher than the air temperature, seawater acts as an absorber of solar radiation energy and affects other objects around it. A marine biota is an object whose growth is influenced by seawater temperature.

The ideal temperature at sea level and seawater for seaweed is 20-32 °C [8]. The speed and direction of the currents can change according to temporal variations. The temporal variation referred to here is the dynamic or time-based change that is reviewed every hour of the day. There are daily dynamics because the direction and speed of flow always change throughout the day. Changes in the direction and speed of currents in a day are caused by tides that occur due to the gravitational force of the earth-sun but also earth- moon, so those tidal phenomena can be observed every half-day, namely day and night [8]. The highest fluctuation of tidal conditions occurs during the full moon or new moon [9]. The variation in maximum current speed due to tides also occurs at full moon or new moon. Seaweed growth in several places with different speed and direction patterns has different characteristics, one of which is the seaweed plant.

The physical and chemical conditions of the water affect the productivity of seaweed [10,11]. The physical factors referred to include seawater temperature and ocean current velocity [3,4,10]. Monitoring the development of marine ecosystems can be done through physical parameters of seawater temperature, speed, the direction of ocean currents and needs to be done in a sustainable manner. The purpose of this study was to analyze the dynamics of daily temporal changes in seawater temperature at several depth points and variations in the speed and direction of ocean currents. Make simple mathematical modeling of ocean current velocity and daily dynamics of seawater temperature in the seaweed growth zone and outside the seaweed growth area. Thermal interaction analysis was carried out on seawater temperature and seawater velocity, to estimate the ideal temperature range and seawater velocity as a zone characterization of seaweed ecological conditions.

2. Methods

This research was conducted in the coastal waters of Batunderang Village, South Manganitu District, Sangihe Regency with a geographical location of 3 ° 20'13.92 "NorthLatitude - 3 ° 22'10.56" North Latitude (3 ° over 20 minutes 13.92 seconds to 3 ° over 22 minutes 10.56) and 125 ° 35'35.52 "- 125 ° 37'19.2" East Longitude, where seaweed naturally flourishes. The research equipment is the Current meter, roll meter, raffia rope,GPS, and writing instruments. The research method used is a descriptive research methodthat describes the characteristics of the daily dynamics of seawater temperature and the direction and speed of ocean currents inside and outside the seaweed growth area. Determination of the measurement position based on the conditions of the ecological characteristics, then measuring the speed and direction of the ocean currents at each position, and then mathematical modeling is made as a physical characterization of the seaweed growth zone. Flow velocity data were collected inside and outside the seaweedgrowing areas, at 1-hour intervals and then tabulated. Current velocity measurements aremade during the full moon with the positions of the earth, moon, and sun in a straight line. Retrieval of seawater temperature (°C) at a depth of 15 cm, 50 cm, 100 cm, and 200cm. Measurements are carried out every hour from 07.00 to 05.00 in the morning the nextday then the data is entered into the tabulation table.

The data analysis techniques used are:

- Analysis of the speed and direction of variations in seawater currents.
- Analysis of changes in seawater temperature at four depth variations.

Our earth is surrounded by two very broad fluids, namely air, and seawater. Both are in astate of motion (dynamic condition), generated by energy from the sun and the gravitational force of the earth. Their movements are interrelated: the wind provides its energy to the surface of the sea to produce ocean currents and ocean currents carry heat energy from one location to another, changing the temperature pattern of the earth's surface and also changing the physical properties of the air above it [8]. Because it is influenced by solar energy fluctuating sinusoid ally so that the appropriate mathematical modeling to describe the pattern of changes in seawater temperature and ocean currents is to use the Fourier function

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as well as according to Beverly et al., 2000 and Ling. 2006,the data distribution in the form of a sinusoid can be approached with the Fourier series [12,13].

Fourier series is a series containing sines and cosines that are used to represent functions in general. In addition, this series is often used as a tool in solving differentialequations, both ordinary differential equations and partial differential equations.

Suppose that f functions are continuous at intervals - L< x <L with periods 2π. Then the fourier series of f(x) is defined:

$$f(x) = \frac{1}{2}a_0 + \sum_{n=1}^{\infty}\left(a_n cos\frac{n\pi x}{L} + b_n sin\frac{n\pi x}{L}\right)$$
$$a_0 = \frac{1}{L}\int_{-L}^{L} f(x)dx \qquad (1)$$

With coefficients

$$a_0 = \frac{1}{L}\int_{-L}^{L} f(x)\, cos\frac{n\pi x}{L}dx\ ,\ \ b_n = \frac{1}{L}\int_{-L}^{L} f(x)\, sin\frac{n\pi x}{L}dx. \qquad (2)$$

If the function f is defined at (-L, L) and f is an even function, the fourierseries of f at (-L, L) is called the fourier cosine series of f at (-L, L) and fourier series in the form:

$$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} a_n cos\frac{n\pi x}{L}$$
$$a_0 = \frac{1}{L}\int_{-L}^{L} f(x)dx = \frac{2}{L}\int_{0}^{L} f(x)dx \qquad (3)$$

With coefficients

$$a_n = \frac{1}{L}\int_{-L}^{L} f(x)cos\frac{n\pi x}{L}dx = \frac{2}{L}\int_{0}^{L} f(x)cos\frac{n\pi x}{L}dx \qquad (4)$$

Constructing the model function form from field data with the following steps:

- Determination of data pairs to construct fourier functions.
- Determination of the number of harmonics.
- Determination of fourier function coefficients for each harmonic.
- Determination of the contribution of each harmonic's diversity and total diversity.
- Constructs the fourier function with the coefficients corresponding to the chosenharmonics.

3. Results and discussion

The waters in Batunderang village are waters with high dissolved oxygen levels andsalinity of 0.09 ppt. These waters have relatively good water circulation because they arelocated between small islands.

(a) (b) (c)

(Source: Field Observation)

Figure 2. (a), (b) and (c) Batunderang coastal ecosystem.

Seawater temperature measurements were carried out at four depth positions, namely 15cm, 50 cm, 100 cm, and 200 cm for 24 hours of measurement. This measurement positionis determined according to Hutabarat et al [14], light can penetrate the water layer to a depth of 100-200meters. The change in seawater temperature every 1 hour of measurement is shown in Figure 2.

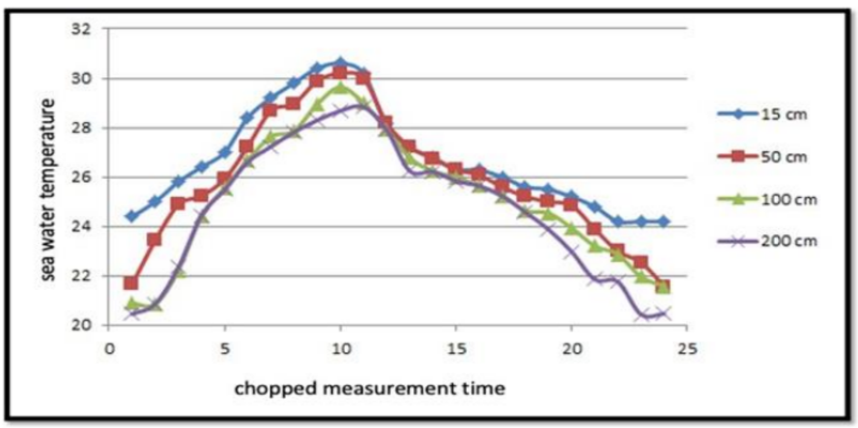

Figure 3. Graph of temporal changes in seawater temperature.

The graph in Figure 3 shows that of the 4 depth points the highest seawater temperature is near sea level and the deeper the ocean current water temperature decreases. The resultsof the measurement of ocean current velocity are expressed in the graph in Figure 3.

Changes in seawater temperature are caused by the flow of heat energy which is entirelycaused by solar radiation [15]. Solar radiation determines the light intensity at a depth andalso greatly affects water temperature [16]. Sunlight that is refracted into the depths of seawater is attenuated so that the temperature of the seawater continues to decrease according to its depth. At a depth of 50 cm from sea level, the temperature decreases, andat a depth of 100 to 200 cm above sea level, it proves that seawater temperature tends to decrease with increasing seawater depth, as stated by Hutabarat et al [14], that the impact of sun irradiation will decrease rapidly with increasing sea depth.

The graph in Figure 3 shows that the seawater temperature at the four observation pointsduring the time range 11.00 - 16.00 WITA shows the same pattern and seawatertemperature varies the highest in the range of 28.6 °C at a depth of 200 cm and 31 °C at a depth of 50 cm. This temperature range is in the ideal temperature range for seaweed growth, as also explained by Michel De San that the ideal temperature for seaweedgrowth is 20-32 °C [17]. The observations also show that in the mangrove area there are rocksthat are strong enough to stick seaweed plants.

There is also a mangrove forest which functions besides holding back waves, it also blocks mud from the land when it rains. This causes the water to be quite clear and a conducive environment for the growth of seaweed.

Figure 4 below shows the pattern of spatial changes in seawater temperature according todepth variations at 07.00, 11.00, and 21.00 WITA.

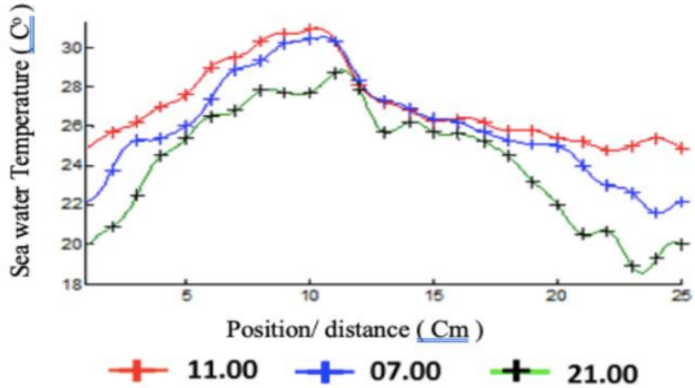

Figure 4. Graph or vertical profile of seawater temperaturewhich is overgrown with seaweed.

Based on Figure 4, the graph of spatial change or temperature change based on seawaterdepth shows almost the same pattern. The red curve is the maximum seawater temperatureat 11.30 WITA when the sun is at its peak. The blue curve is seawater temperature at 07.00 WITA, which is when the sun just rises, which makes the elevation angle deviationfrom the position of the sun to the sea, while the green curve is 21.00 WITA or at night, the seawater temperature decreases but it still stores energy heat from solar radiation. The seawater temperature at night is still higher than the air temperature at night. The main energy obtained by the oceans is energy from the sun so that the position of the sun on the sea level also affects the energy from sunlight that is absorbedby the ocean.

The temporal change in the velocity of the ocean currents in Figure-3, gives a relatively same curve pattern, namely 4 wave crests and 4 valleys, which means that there have been two tides and two tides during 24 hours of measurement. This event resulted in 4 variations of current speed data from 24 measurements made in hourly time intervals. Wibisono states that every tidal or tidal activity process creates a flow [18]. The currentdirection occurs periodically in these waters, namely to the southwest when seawater moves towards the tide and to the northeast when the sea waterfalls. The speed and direction patterns of the currents are almost the same as the tidal conditions of seawater,which are influenced by the rise and fall of sea levels [15]. Wibisono states that every process of tidal or ebb activity creates a flow [18].

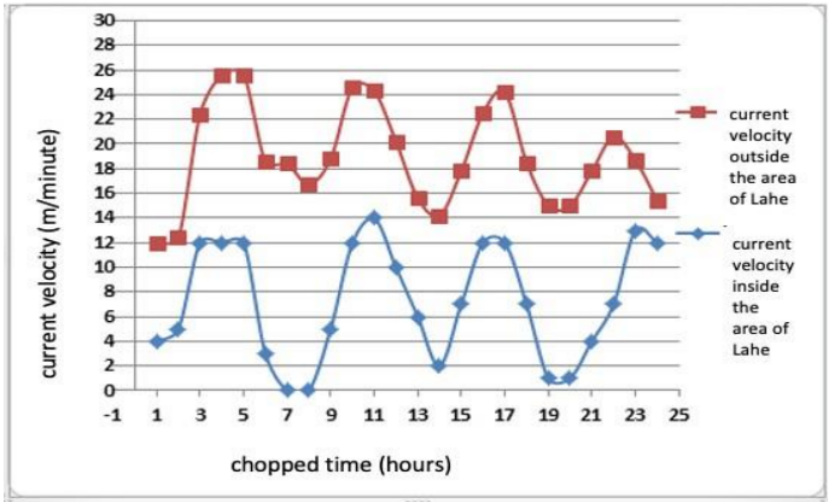

Figure 5. Graph of current velocity profile inside and outside the seaweed growth area.

Observations and measurements are carried out at 11.00-16.00 WITA, at the 6th to 10th measurement the seawater temperature gradually rises, when seawater absorbs heat energy from sunlight. The increase in seawater temperature is accompanied by an increasein the speed of currents in the sea which is also triggered by the tides at that time. Poncomulyo et al. explained that seawater temperature is influenced by sunlight, depth, currents, and tides [19].

The temporal change in the velocity of the ocean currents gives a relatively similar curvepattern, namely 4 wave crests and 4 valleys, which means that there have been two tidesand two tides during 24 hours of measurement. This event produces 4 variations of currentvelocity data from 24 measurements made in hourly time intervals. The current velocity in the seaweed area is relatively small so that the plants thrive naturally in that location. In general, in seaweed farming, a location with minimal current velocity is an ideal location.

According to the number of transects observed, 2 functions and a graph of the temporal change in ocean current velocity were obtained, namely at position-1 in the seaweed areaand at position-2 outside the seaweed area. Based on the data on the contribution of diversity, 12 harmonics are obtained (100 percent precision) so that the Fourier functioncan be written as follows:

Mathematical model of ocean current velocity in seaweed plant areas

$$F(t) = 7.400 + 0.534\,\mathrm{COS}\,(2\pi t/24) + 0.140\,\mathrm{SIN}\,(2\pi t/24) + 2.527\,\mathrm{COS}\,(4\pi t/24) + 1.075\,\mathrm{SIN}\,(4\pi t/24) + 0.053\,\mathrm{COS}\,(6\pi t/24) + 0.471\,\mathrm{SIN}\,(6\pi t/24) - 1.647\,\mathrm{COS}\,(8\pi t/24) - 5.314\,\mathrm{SIN}\,(8\pi t/24) + 0.655\,\mathrm{COS}\,(10\pi t/24) + 0.163\,\mathrm{SIN}\,(10\pi t/24) + 0.894\,\mathrm{COS}\,(12\pi t/24) - 0.672\,\mathrm{SIN}\,(12\pi t/24) + 0.239\,\mathrm{COS}\,(14\pi t/24) - 0.448\,\mathrm{SIN}\,(14\pi t/24) + 0.205\,\mathrm{COS}\,(16\pi t/24) - 0.117\,\mathrm{SIN}\,(16\pi t/24) + 0.168\,\mathrm{COS}\,(18\pi t/24) - 0.294\,\mathrm{SIN}\,(18\pi t/24) + 0.745\,\mathrm{COS}\,(20\pi t/24) + 0.416\,\mathrm{SIN}\,(20\pi t/24) + 0.309\,\mathrm{COS}\,(22\pi t/24) + 0.284\,\mathrm{SIN}\,(22\pi t/24) - 0.083\,\mathrm{COS}\,(6\pi t/24) + 0.411\,\mathrm{SIN}\,(24\pi t/24)$$

Mathematical model of ocean current velocity outside the seaweed plant area

$$F(t) = 18.756 - 1.538\,\mathrm{COS}(2\pi t/24) + 1.293\,\mathrm{SIN}(2\pi t/24) - 1.565\,\mathrm{COS}(4\pi t/24) + 0.280\,\mathrm{SIN}(4\pi t/24) - 1.174\,\mathrm{COS}(6\pi t/24) + 0.116\,\mathrm{SIN}(6\pi t/24) - 2.358\,\mathrm{COS}(8\pi t/24) - 4.034\,\mathrm{SIN}(8\pi t/24) + 0.165\,\mathrm{COS}(10\pi t/24) + 0.655\,\mathrm{SIN}(10\pi t/24) + 0.773\,\mathrm{COS}(12\pi t/24) - 0.227\,\mathrm{SIN}(12\pi t/24) + 0.706\,\mathrm{COS}(14\pi t/24) + 0.057\,\mathrm{SIN}(14\pi t/24) + 0.089\,\mathrm{COS}(16\pi t/24) + 0.603\,\mathrm{SIN}(16\pi t/24) + 0.17\,\mathrm{COS}(18\pi t/24)$$

$$- 0.05\ \mathrm{SIN}(18\pi t/24) + 0.479\ \mathrm{COS}(20\pi t/24) - 0.005\ \mathrm{SIN}(20\pi t/24) - 0.15\ \mathrm{COS}(22\pi t/24) - 0.481\ \mathrm{SIN}(22\pi t/24) - 0.353\ \mathrm{COS}\ (24\pi t/24) + 0.287\ \mathrm{SIN}(24\pi t/24)$$

This mathematical model describes the pattern of changes in the speed of ocean currentsin the waters of Batunderang Village which follows the pattern of the Fourier function.

4. Conclusion

Batunderang Village marine zone is suitable for seaweed cultivation. Seaweed that grows in the seawaters of Batunderang Village thrives because it is supported, among other things, by physical parameters of temperature at a depth of 50 cm to 200 cm at 11.00-16.00 WITA varies between 25 ° C to 31 ° C. The average flow velocity in the seaweed planting area is 7.4 meters/minute, and outside the planted area is 18.75meters/minute with the direction of the ocean currents, namely southwest at high tide andeast at low tide. Mangroves and coral reefs in the seawaters of Batunderang Village can provide comfort for the growth of seaweed. Temperature, speed, and direction of ocean currents can be basic data to engineer ideal natural conditions for the growth of seaweed.Physical parameters other than temperature and current strength can also be observed in other studies to obtain complete data regarding the physical parameters that affect the growth of seaweed in Batunderang Village. The pattern of changes in ocean currents canbe expressed in a mathematical model using the Fourier series. This physical data can bea useful physical parameter for monitoring seaweed cultivation and also for planning thedesign of a suitable natural environment for seaweed growth.

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