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ADVANCES IN SOCIAL HUMANITIES RESEARCH

Study of Chlorophyl-A Variability in Bone Bay Waters During High Wave Events

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Abstract
Research has been carried out on the distribution of chlorophyll-a in the waters of Bone Bay during high wave events based on the parameters of sea surface temperature, wind speed and ocean currents. The aim of this research is to analyze parameters related to high waves which influence chlorophyll-a concentrations in the waters of Bone Bay. Chlorophyll-a patterns in Bone Bay waters were studied based on Aqua MODIS satellite data for chlorophyll-a data and ECMWF for wind speed, sea surface temperature and ocean current data. The average value was determined using Aqua MODIS and ECMWF satellite data for 10 years from 2011 to 2020. These parameters were analyzed to determine the correlation with chlorophyll-a. The calculation results show that sea surface temperature and wind speed decreased after high waves, while ocean currents and chlorophyll-a increased after high waves in Bone Bay waters. The correlation between chlorophyll-a and wind speed is 0.15, with sea surface temperature -0.44, and with ocean currents -0.26. Spatially, high concentrations of chlorophyll-a are found in the coastal waters of the South Sulawesi region with chlorophyll-a concentrations reaching 0.4-5 mg/m3. Temporally, high chlorophyll-a concentrations occur after high wave events with an average chlorophyll-a concentration of 0.32 mg/m3.
Keywords: high waves, chlorophyll-a, wind speed, sea surface temperature, and ocean currents.

INTRODUCTION

Bone Bay is A bay on Sulawesi Island which is between South Sulawesi Province (to the west and north) and Southeast Sulawesi Province (next to east) (Widyastuti et al., 2019). Bone Bay borders directly to the Flores Sea. Bone Bay is one of them bay the largest in Indonesia and has an elongated shape from north to south (Wilson et al., 2019). Surrounded by mountains, bay it has topography base varying seas with changing depths from shallow areas on the coast until part the deepest that reaches more from 2000 meters in the center bay (de Wet & Compton, 2021). According to Balcombe (2016), depth the sea in Bone Bay is very varied, reaching 2000 meters to direction free beach next door south. Depth shallow between 50 and 200 meters along the length west, north and east coasts with morphology base sea rather wavy and steep to part south (Xu et al., 2016). This elongated and deep shape creates unique hydrodynamic conditions, where the current sea influenced by factors like wind monsoons and tides. Strong and dynamic

current This role important in distribution nutrients and organisms' sea in waters Bone Bay.

Temperature and salinity conditions waters Bone Bay shows significant variation depending on the season and water depth. Temperature normal water surface range between 27°C to 31 °C, with temperatures above tall during season hot and lower during season Rain. Salinity in the bay This relatively stable, though can influenced by fresh water flow from rivers that empty into the bay, especially during season Rain. Variation temperature and salinity This influence distribution and abundance various type phytoplankton and zooplankton, which are base from chain food sea (Apri & Iskandar, 2020).

Productivity in Bone Bay is sufficient high, supported by existence fertile phytoplankton. Chlorophyll -a as indicator main productivity phytoplankton show exists variability affected by change seasonality and environmental conditions like intensity light sun and availability nutrients. Nutrients This usually obtained from upwelling (rising nutrient -rich water from depth) that occurs consequence current sea and wind monsoon. High productivity This support diversity abundant biodiversity, in various fish species, mollusks, and organisms' sea other (Irfan & Alatawi, 2019).

Diversity life in Bone Bay is not only covers phytoplankton and zooplankton, but also reefs coral and fields Seagrass is an important habitat for Lots species sea. Ecosystem reef coral in the bay This provide place shelter, protection, and food source for various types of fish and invertebrates sea. Seagrass beds, on the other hand, work as place spawning and nursery areas for Lots fish species, as well help guard water quality by absorbing nutrients excessive. Combination ecosystem This make Bone Bay as one center diversity biological sea in Indonesia (Rumpa et al., 2022).

Dynamics ocean-atmosphere regional scale occurs in the waters Alleged Bone Bay can affect mass characteristics the water in a way direct nor no directly, among others Indonesian Cross Flow (ARLINDO) of which 80% flows through the Makassar Strait and parts turn to East direction passing through the Flores Sea in the south Bone Bay towards the Banda Sea (Atmadipoera et al., 2024). Another mechanism that is also present in Teluk Bone is wind Southeast Monsoon and Northwest Monsoon occur in a way seasonality in Indonesia (Ayyamperumal et al., 2024). Wind seasonal too influence Ekman transport is called wind-driven Ekman flow, which can move the mass of water and nutrients in it Rivas (2019) for example through *upwelling* and *downwelling*, such as Ekman *upwelling which* occurs in July-September and Ekman *downwelling* in January-March in the Banda Sea (McCreary & Shetye, 2023), so can influence distribution abundance of marine life.

Existence creature live on something ecosystem No regardless of physical processes in the environment the surrounding area can support metabolism or cycle life daily. Connecting physical factors pattern distribution between creature live from coast to sea free is salinity, temperature and movement water mass (Snoeijs-Leijonmalm & Andrén, 2017). Energy waves and currents sea is factoring important physical factors in the ecosystem coast as well as areas influenced by tides.

Resource fisheries located in the area Bone Bay is asset strategic to be developed on an activity basis economics with purpose prosperity and improvement of coastal community's acquisition income native to the region. The potential for fish resources, especially pelagic fish, in Bone Bay is sufficient big where is the fish? generally create a water area Bone Bay as a track area the migration. Fish have the ideal temperature and chlorophyll for its growth and development. The ideal temperature and chlorophyll for fish in the range temperature 27.9°C – 28.2°C and chlorophyll -a between 0.3 mg/m³– 3.9 mg/m³ (Retraubun et al., 2023).

Production result fishery catch in 2022 amounting to 436,735.7 tons with value amounting to IDR 11,812,528,786,000.-. One of abundant pelagic fish resources caught by fishermen in the waters Teluk Bone is a skipjack fish. Skipjack tuna is one of most important type of fish Good as commodity export nor as material domestic consumption. Number of skipjack tuna catches in 2022 in the waters Bone Bay amounted to 79,534.3 tons with value amounting to IDR 2,209,536,287,000, - which is an increase amounting to IDR 196,212,687,- compared to 2021.

When happen wave high in the water Bone Bay, got it happen possible changes in water conditions impact on variability chlorophyll -a. Wave tall can bother stability waters, so can influence plankton production in waters. Change plankton production can impact on variability chlorophyll -a in water Bone Bay (Gabel et al., 2017).

Wind parameters is one of the main parameters in influencing water characteristics (Shu et al., 2024). Wind blowing over the surface sea in general in a way direct will influence oceanographic parameters another one of them that is *upwelling.* According to Randelhoff (2018), *upwelling* is increasing sea water mass from something inner layer to layer surface. This upward movement bring as well as hot water colder, salinity high, and rich in nutrients surface, for one that is chlorophyll -a. Plenty of chlorophyll -a contained in phytoplankton Bradley (2019) which is producers in the ecosystem sea. Information about variability spatial chlorophyll -a on the surface the sea is very important. Because can used for make it easier management and utilization of fisheries resources.

A number of research that has been done for describe aspect oceanography physics in Bone Bay, including Jishad (2021)found that direction current surface sea Bone Bay from January to April is dominant from east direction, while from May to December dominant from west direction. Speed current surface sea surface from January to December generally low (0-5 cm/s), but in January in the southern part of Bone Bay it is sufficient high in value range between 25-40 cm/s. Safrudin (2016) also studied that Temperature Relative Sea Level Warm in the Waters beach especially in the northern part of Bone Bay, as well as density its chlorophyll -a. According to Rosalina et al (2023) temperature surface sea the highest in Bone Bay occurs in November around between 29.36º-34.52ºC with an average value of 30.83ºC and temperature surface sea Lowest occurred in August around between 26.64º-32.32ºC with an average value of 28.70ºC.

Other research as done by Wicaksono (2020) where concentration chlorophyll -a corresponds to temperature surface sea, where Concentration chlorophyll -a increases

high at the moment temperature surface sea low, meanwhile speed current surface and bulk Rain not enough influential to concentration chlorophyll -a in water around Makassar city. Intansari et al (2018) also found that spread chlorophyll -a and temperature surface sea in the waters of the Karimata Strait show that concentration high chlorophyll -a found in coastal areas and lower in water free beach. Temporary spread chlorophyll -a and temperature surface sea monthly show concentration highest chlorophyll -a and temperature surface sea highest available in May.

This research aims for analyze influence incident High Wave against variability chlorophyll -a in Water Bone Bay. Formulation problem covers identification time incident wave high, analysis spatial average Speed Wind, Temperature Sea Level, Ocean Currents, and Chlorophyll -a during 2011-2020, as well connection between factor physique sea with concentration Chlorophyll -a. Benefit from study This among other things, providing understanding about impact wave tall to productivity phytoplankton, increasing knowledge scientific in science marine and ecological sea, providing information for fisherman For increase productivity fish catch, and encourage technological development monitoring more sea advanced.

RESEARCH METHODS

This research use method Analytic Correlational For explain connection between variables studied, as well predict magnitude changes to variables tied to change variable free. Held during six months from January to June 2024 at BMKG Station Meteorology Sangia Nibandera Kolaka, research This focuses on relationships between speed wind, temperature surface sea, and currents sea with variability chlorophyll -a in Water Bone Bay moment incident wave tall from 2011 to 2020. Data used to include wave data sea, chlorophyll -a, speed wind, temperature surface sea, and currents sea, which was taken from various sources such as the Copernicus Climate Change Service and the NASA Ocean Biology Processing Group. Analysis done in a way spatial and temporal for understand dynamics variables the before and after incident wave tall. The analytical method used covers Pearson correlation for evaluate connection between variables and analysis descriptive for describe variability chlorophyll -a in Bone Bay in response to wave tall.

RESEARCH RESULTS AND DISCUSSION

A. Research result

1. Incident High Waves in the Water Bone Bay

For know events wave high in the waters Bone Bay, then done analysis tall wave in a way spatial for 10 years that is from 2011 to 2020 with the number grid points of 35 points. Following is high data wave maximum earned each year from calculation tall wave sea for each page hour in meters.

Table 1. Wave Height Maximum 2011-2020 In the Water Bone Bay

No	Year	Date	Wave Height Maximum (meters)
1	2011	January 12, 2011	2,236
2	2012	January 8, 2012	1,713
3	2013	09 January 2013	2,643
4	2014	January 16, 2014	2,637
5	2015	03 January 2015	2,359
6	2016	December 21, 2016	1,649
7	2017	February 2, 2017	2,744
8	2018	January 30, 2018	1,985
9	2019	January 22, 2019	2,464
10	2020	December 19, 2020	1,732

Based on the data in table 1 then there were 3 incidents wave tall Where mark wave the sea bigger from 2.5 meters and less of 4.0 meters, namely on January 9, 2013 with height wave 2,643 meters, January 16 2014 with height waves 2,637 meters, and on February 2 2017 with high wave 2,744 meters.

2. Analysis in a way spatial average Chlorophyll -a, Velocity Wind, Temperature Sea Surface, and Ocean Currents in Water Bone Bay for 10 years and conditions before and after happen wave tall

a. Average for 10 years (2011-2020)

For know exists changes to Meteorological parameters that will occur discussed, then needed normal value or average value of the parameter. Following is the average chlorophyll -a, temperature surface sea, speed wind, and current deep sea 10 years start from 2011 to 2020.

1) Chlorophyll -a

After done concentration data processing chlorophyll -a from the MODIS *Aqua* sensor using device ArcGIS 10.8 software, then obtained the average value of chlorophyll -a for 10 years is shown in Figure 1 and is obtained average value on Peraitan Bone Bay is 0.42 mg/m $^{3.}$ On picture can seen spread chlorophyll -a in Water Bone Bay is very varied start from 0.1 mg/m ^{3} to 7 mg/m $^{3.}$

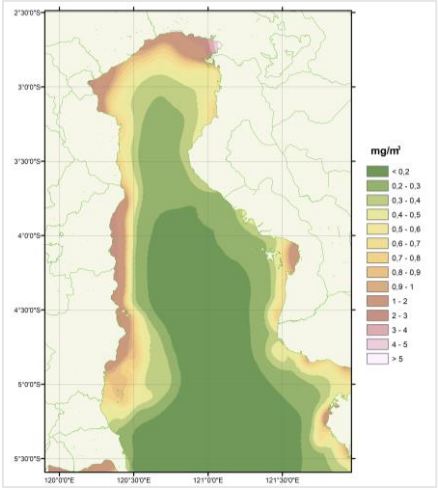

Figure 1. Average Concentration Chlorophyll -A for 10 Years (2011-2020)

2) Speed Wind

After done data processing speed ECMWF wind by using device soft GRADS get the average speed wind for around 10 years between 2 - 7 knots in Water Bone Bay shown in Figure 2.

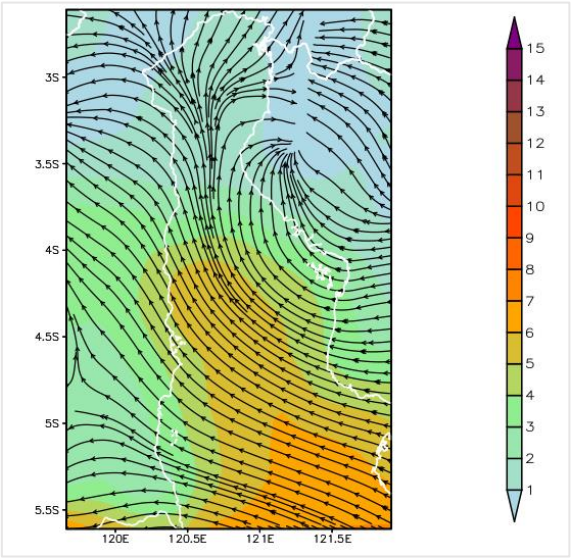

Figure 2. Average Speed Wind For 10 Years (2011-2020)

3) Temperature Sea level

After done temperature data processing surface ECMWF sea using device ArcGIS 10.8 software obtained the average temperature surface sea for 10 years i.e around 27.5 – 30.1 °C in Water Bone Bay shown in figure 3.

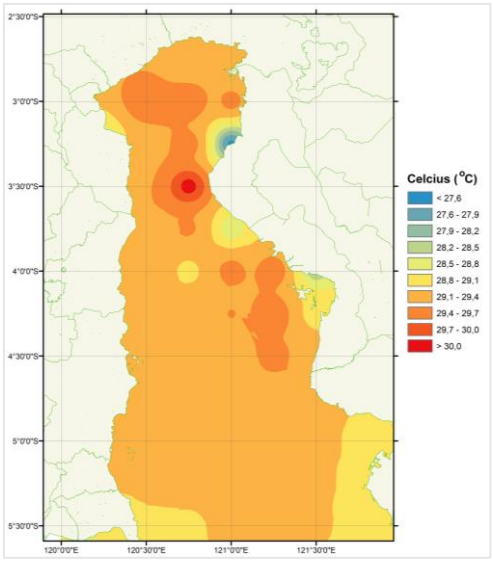

Figure 3. Average Temperature Sea Level for 10 Years (2011-2020)

4) Sea wave

After done data processing speed current sea by using device soft GRADS get the average speed current sea for around 10 years between 0.1 – 0.3 m/s in water Bone Bay shown in Figure 4.

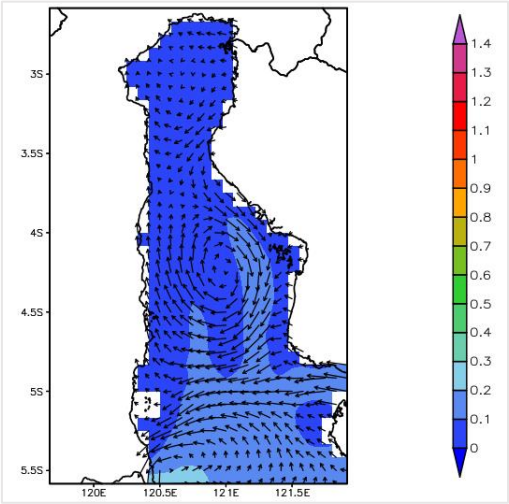

Figure 4. Average Speed Ocean Currents for 10 Years (2011-2020)

b. Before High wave

1) Before High Wave on 09 January 2013 (02 – 08 January 2013)

Water Conditions Bone Bay before happen High Wave on January 09, 2024 visible that in Figure 5 (a) Concentration chlorophyll -a whole that is around 0.1 mg/m ^{3} – 3.2 mg/m $^{3.}$ Concentration chlorophyll -a is highest found in the waters Bone Bay approx coast beach East Luwu and North Kolaka, namely 1 mg/m ^{3} up to 3.2 mg/m $^{3.}$ Based on Figure 5 (b) speed average wind range between 3 to 13 knots. Figure 5 (c) shows mark temperature surface sea

in Waters Bone Bay ranges between 28.2°C – 30.0°C and Figure 5 (d) shows mark current sea of 0.1 – 0.8 m/s.

2) Before High Wave January 16 2014 (January 9 - 15 2014)

Water Conditions Bone Bay before happen High Waves on January 16, 2014 are visible that in Figure 6 (a) where concentration chlorophyll -a whole that is around 0.1 mg/m ^{3} – 1.6 mg/m $^{3.}$ Concentration chlorophyll -a is highest found in the waters Bone Bay approx coast beach Bone Regency is 0.8 mg/m ^{3} up to 1.6 mg/m $^{3.}$ Based on Figure 6 (b) speed average wind range between 3 to 13 knots. Figure 6 (c) shows mark temperature surface sea in Waters Bone Bay ranges between 28.5°C – 30.0°C and Figure 6 (d) shows mark current sea of 0.1 – 0.6 m/s.

3) Before High Wave on 02 February 2017 (26 January – 01 February 2017)

Water Conditions Bone Bay before happen High Waves on February 02, 2017 are visible that in Figure 7 (a) where concentration chlorophyll -a whole that is around 0.1 mg/m ^{3} – 0.3 mg/m $^{3.}$ Based on Figure 7 (b) speed average wind range between 3 to 11 knots. Figure 7 (c) shows mark temperature surface sea in Waters Bone Bay ranges between 29.4°C – 30.8°C and Figure 7 (d) shows mark current sea of 0.1 – 0.5 m/s.

c. After High wave

1) After High Wave January 9 2013 (January 10 – 16 2013)

After done chlorophyll -a data processing, speed wind, temperature surface sea and currents sea on January 10-16 2013, water conditions Bone Bay after happen High Waves on January 9, 2013 are visible that in Figure 8 (a) where concentration chlorophyll -a whole that is around 0.1 mg/m ^{3} – 2 mg/m $^{3.}$ Based on Figure 8 (b) speed average wind range between 2 to 11 knots. Figure 8 (c) shows mark temperature surface sea in Waters Bone Bay ranges between 28.5°C – 30.5°C and Figure 8 (d) shows mark current sea of 0.1 – 0.7 m/s.

2) After High Wave January 16 2014 (January 17 – 23 2014)

After done chlorophyll -a data processing, speed wind, temperature surface sea and currents sea on 17-23 January 2014, water conditions Bone Bay after happen High Waves on January 16, 2014 are visible that in Figure 9 (a) where concentration chlorophyll -a whole that is around 0.1 mg/m ^{3} – 2 mg/m $^{3.}$ Based on Figure 9 (b) speed average wind range between 3 to 12 knots. Figure 9 (c) shows mark temperature surface sea in Waters Bay Bone ranges between 27.9°C – 30.0°C and Figure 9 (d) shows mark current sea of 0.1 – 0.8 m/s.

3) After High Wave on 02 February 2017 (03 – 09 February 2017)

After done chlorophyll -a data processing, speed wind, temperature surface sea and currents sea on 03 – 09 February 2017, water conditions Bone Bay after happen High Waves on February 02, 2017 are visible that in Figure 10 (a) where concentration chlorophyll -a whole that is around 0.1 mg/m ^{3} –

2 mg/m ^{3,} Based on Figure 10 (b) speed average wind range between 3 to 13 knots. Figure 10 (c) shows mark temperature surface sea in Waters Bone Bay ranges between 28.8°C – 30.8°C and in Figure 10 (d) shows mark current sea of 0.1 – 0.8 m/s.

3. Correlation Speed Wind, Temperature Sea Surface, and Ocean Currents with concentration Chlorophyll -a in Water Bone Bay

a. Correlation Speed Wind and Chlorophyll -a

Connection between speed wind with concentration chlorophyll -a shows exists correlation positive with value namely 0.15, which means This is correlation positive that is moment speed wind strengthen so concentration chlorophyll -a increases and vice versa, when speed wind weakened so concentration chlorophyll -a decreases. A value of 0.15 is included correlation category weak.

b. Correlation Temperature Sea Level and Chlorophyll -a

Connection between temperature surface sea with concentration chlorophyll -a has a correlation negative level moderate namely -0.44, which means moment temperature surface the sea rises then concentration chlorophyll -a decreases and vice versa, when temperature surface sea down so concentration chlorophyll -a increases.

c. Correlation Ocean Currents and Chlorophyll -a

Connection between current sea with concentration chlorophyll -a shows mark correlation negative -0.26, correlation This including correlation negative weak which means moment current the sea rises then concentration chlorophyll -a decreases and vice versa, when current sea down so concentration chlorophyll -a increases.

4. Analyze variability concentration and distribution chlorophyll -a in Water Bone Bay before and after incident High wave.

Average concentration value chlorophyll -a as shown in table 2 for 10 years is 0.42 mg/m ^{3,} the average concentration chlorophyll -a before incident wave tall amounting to 0.347 (2013), 0.256 (2014), and 0.195 (2015). Whereas mark concentration chlorophyll -a after incident wave tall amounting to 0.321 (2013), 0.295 (2014), and 0.346 (2015).

Table 2. Comparison Chlorophyll -a 10 Year Average, Before and After High wave

High wave	10 years (2011-2020)	Before	After
2013	0.42 2025 grid points	0.347 344 grid points	0.321 1321 grid points
2014		0.256 945 grid points	0.295 361 grid points
2017		0.195	0.346

	163 grid points	748 grid points

B. Discussion

1. Incident High Waves in the Water Bone Bay

Analysis wave sea in a way spatial show that in the range 10 years from 2011 to 2020 happen happened several times wave high in the waters Bone Bay. Based on table 4, 3 incidents were obtained wave high in value highest occurred in 2017 which was high wave reached 2,744 meters, then in 2013 the height waves of 2,643 meters, and the last in 2014 with high wave reaches 2,637 meters. Furthermore, will analyzed water conditions before and after incident third wave tall the. Water conditions will be dialysis form chlorophyll -a, speed wind, temperature surface sea and currents sea.

2. Analysis in a way spatial average Chlorophyll -a, Velocity Wind, Temperature Sea Surface, and Ocean Currents in Water Bone Bay for 10 years and conditions before and after happen wave tall

By general spread chlorophyll -a in Water Bone Bay based Figure 4 more high in water areas beach consequence from the height supply derived nutrients from land and river water runoff and vice versa tend lower in the remote area beach Because no exists supply nutrients from mainland in a way direct. This is in accordance with research conducted by Dessne (2015) which stated that spread chlorophyll -a and temperature surface sea in the waters of the Karimata Strait show that concentration high chlorophyll -a found in coastal areas and lower in water free beach.

Speed wind higher in the remote area beach based on figure 4, p the due to lose areas beach not enough obstacle like buildings, trees, or mountains that can obstruct Genre wind so that wind can blowing more freely and with more speed tall. For temperature surface sea tend varies but generally warmer in the outer region beach compared to coastal areas the beach. Results obtained in accordance with research conducted by Struzik (2015) which concluded that in a way spatial, waters free beach or far away from coast will have more temperature tall compared to waters near coast. Whereas for current sea in Waters Bone Bay in general general tend low where the Bone Bay area is part south taller compared to part north.

Concentration chlorophyll -a after incident wave tall increase compared to before incident wave tall for 2014 and 2017, medium for 2013 occurred decline concentration chlorophyll -a. The same thing happens For current inclined sea more tall after incident for 2014 and 2017 and beyond low for 2013.

Different from chlorophyll -a and current sea, on the contrary temperature conditions surface sea after incident wave tall experience obedience temperature for 2014 and 2017, and for 2013 occurred increase temperature surface sea. Whereas For speed wind after wave high in 2013 and 2014 occurred decline speed and for 2017 it happened enhancement speed wind.

3. Correlation Speed Wind, Temperature Sea Surface, and Ocean Currents with concentration Chlorophyll -a in Water Bone Bay

Correlation value between chlorophyll -a with speed wind and current the sea has value correlation level weak, meanwhile correlation between chlorophyll -a with temperature surface the sea has a correlation negative level moderate, value negative indicated pattern connection between second variable have connection backwards. It means If mark temperature surface sea high, then mark chlorophyll -a will become low (and vice versa), the same This is the case with research conducted by Astrijaya Sidik (2015) regarding accuracy mark concentration chlorophyll -a and temperature surface sea using sensing data far out in the water island alanggantang park national nineg which is obtained mark correlation of -0.234.

Connection between chlorophyll -a with temperature surface sea in a way spatial as shown in figure 5 to figure 10 can be seen that area that has concentration chlorophyll -a which tends to have temperature surface more sea low, and vice versa in areas that have concentrations low chlorophyll -a have temperature surface relative sea warmer compared to surroundings. Whereas For speed wind and current the sea in Figure 5 to Figure 10 tends to have a similar pattern the same, which is speed wind and current the sea in the southern part of Bone Bay tends to be taller compared to speed wind and current sea in the northern Bone Bay area.

Correlation value from third included variables category weak and moderate indicated that variable it has no influence too significant to change mark concentration chlorophyll -a in Water Bone Bay.

4. Analyze variability concentration and distribution chlorophyll -a in Water Bone Bay before and after incident High wave.

Concentration value chlorophyll -a after incident wave tall tend increase compared to before incident wave high, p this is also visible in the analysis spatial that has been done Where seen exists enhancement concentration chlorophyll -a after incident wave tall although value Still is below the average concentration chlorophyll -a for 10 years. This matter possibility Because exists some data at grid points are not read by satellite caused by existence cover obstructing clouds so that reduce mark the average concentration of chlorophyll -a where most the grid points are in coastal areas beaches that have value concentration reactive chlorophyll -a taller.

CONCLUSION

Based on results and discussions that have been carried out explained, yes concluded that during range from 2011 to 2020, there are three incident wave tall significant in the waters Bone Bay, namely on 09 January 2013, 16 January 2014, and 02 February 2017. After incident wave high, average temperature surface sea and speed wind experience decrease, temporary current sea and concentration chlorophyll -a experiences enhancement. Analysis correlation show weak relationship until moderate between speed wind, temperature surface sea, and currents sea with concentration chlorophyll -a. By spatial, concentration highest chlorophyll -a found in waters coast beaches of the South Sulawesi region, reaching 0.4-5 mg/m3, with an average concentration of 0.32 mg/m3 after happen wave tall. For study Next, it is recommended for increase resolution spatial

and temporal by expanding point and range time study To use get more understanding detailed about dynamics chlorophyll -a in response to incident wave high in the waters Bone Bay.

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