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Impact of Monsoon to Aquatic Productivity and Fish Landing at Pesawaran Regency Waters

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Abstract. Monsoon variability influences the productivity processes in the ocean and has different responses in each waters. Furthermore, variability of marine productivity affects to the fisheries resources fluctuation. This research has conducted using descriptive method to investigate the consequences of monsoon variability to aquatic productivity, sea surface temperature (SST), fish catches, and fish season periods at Pesawaran Regency waters, Lampung. Variability of aquatic productivity was determined based on chlorophyll-a indicator from MODIS satellite images. Monsoon variability was governed based on wind parameters and fish catches from fish landing data of Pesawaran fish market. The result showed that monsoon variability had affected to aquatic productivity, SST, and fish catches at Pesawaran Regency waters. Maximum wind speed and lowest SST occurred twice in a year, December to March and August to October, which the peaks were on January (2.55 m/s of wind speed and 29.66ºC of SST) and September (2.44 m/s of wind speed and 29.06ºC of SST). Also, Maximum aquatic productivity happened on January to March and July to September, which it was arisen simultaneously with maximum wind speed and the peaks was 0.74 mg/m^3 and 0.78 mg/m^3, on February and August respectively. The data showed that fish catches decreased along with strong wind speed and low SST. However, when weak wind speed and high SST occurred, fish catches increased. The correlation between Catch per Unit Effort (CPUE) with SST, wind speed, and chlorophyll-a was at value 0.76, -0.67, and -0.70, respectively. The high rate fish catches in Pesawaran emerged on March-May and September-December.

Keywords: Monsoon variability, aquatic productivity, Pesawaran Regency, sea surface temperature, fisheries resources

1. Introduction

Pesawaran Regency waters, located contiguity to Sunda Strait, has considerable marine fisheries resources. The area of this waters is supposed around 689 km² or 68.900 Ha with 96 km of coastline and 50 m of mean water depth. The waters condition has fish catches prospectively, but it is not employed yet. Until now, fish demand consumed by tourists is imported from outside Pesawaran Regency.

The problem has been occurred in fish-catching industries to increase the catches because there are difficulties to determine the lowest fish catches season and to find potential fishing ground [1]. Moreover, it is caused by Unpredicted annual climate variability conditions [2]. Due to the limitation of understanding about these problems, fish catches activity still has some drawbacks, such as ineffectiveness, inefficiency, also time and fuel consuming.

Annual climate variability caused by monsoon variability which the effect to aquatic productivity has been investigated by some researchers including [3] [4] [5] and [6]. Correlating to biological conditions of the ocean, monsoon variability, particularly, can trigger the change of marine productivity parameter including the change of chlorophyll-a indicator [7] [8] [9].

The different responses of each waters to monsoon variability become the problem of this research. In Pesawaran Regency, there were not researchers studying the responses of this waters to monsoon variability yet. Therefore, this research was focused to investigate Pesawaran waters responses to monsoon variability. The research area at Pesawaran waters and its round are described in Figure 1.

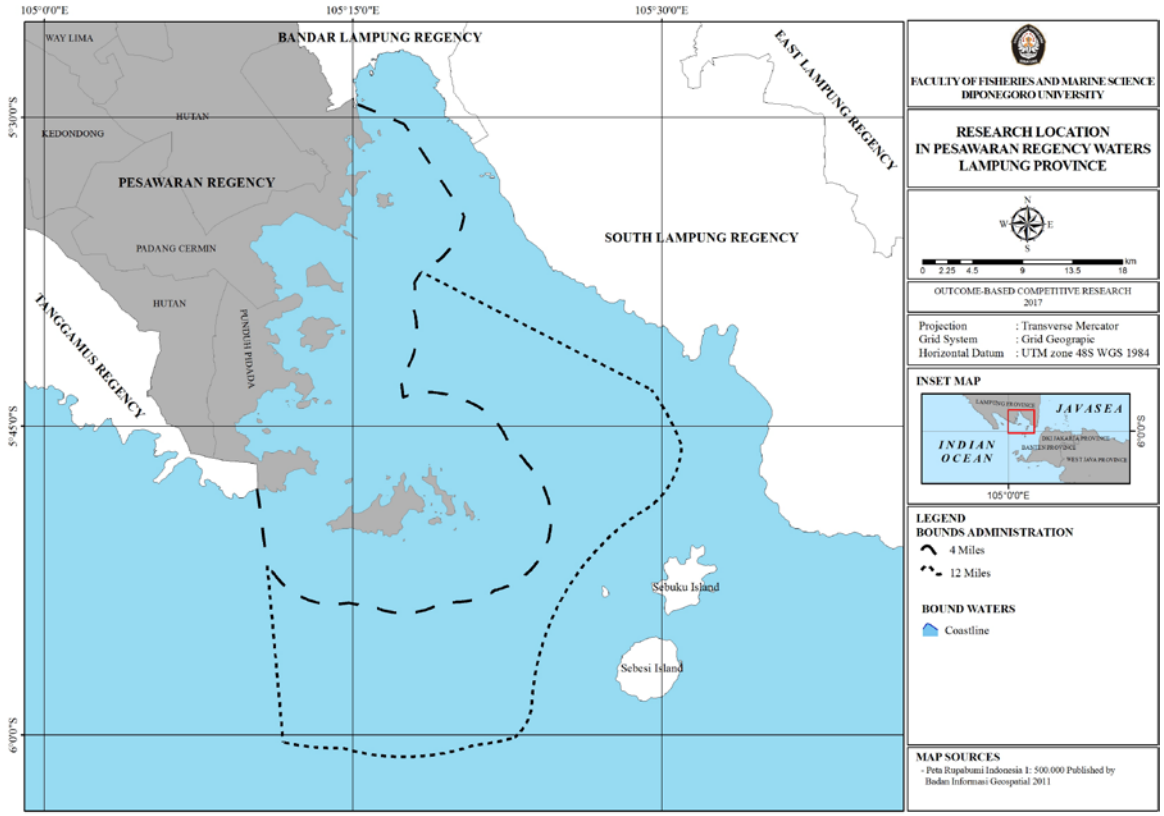

Figure 1. The research location at Pesawaran waters and its round. The waters bound 4 miles and 12 miles are marked by broken line and dotted line.

2. Materials and methods

The primary materials in this research were satellite-based remote sensing data [10] [11] which were MODIS data, spatial distribution of chlorophyll-a and monthly sea surface temperature (SST), from Aqua and Terra satellite, and monsoon variability including wind parameters, wind speed and direction, also fisheries data. Because monsoon variability was considered per month, the data used in the research were monthly data.

This research employed descriptive method. Firstly, it was done by considering monthly climatologist mean of monsoon variability in a year; then it was correlated to variability of productivity using chlorophyll-a indicator at Pesawaran waters. Secondly, SST data were described to know what phenomena was occurring at the time of research. Finally, all parameters were analysed to

understand the influences to the lowest and the highest catches based on monthly fish landing data. To achieving the clarity in this research, problem solving methods were divided into three steps.

2.1. Primary and secondary data

Primary and seconday data were gathered from websites, national governments, and field survey including:

1. Monsoon data, wind speed and direction, collected from European Centre for Medium-Range Weather Forecasts (ECMWF), downloaded from http://www.ecmwf.int, have 1/12 degrees (9.17 km) spatial resolution. These data were analysed using SeaDAS 7.0 and mapping software.
2. Monthly SST and chlorophyll-a data were collected from MODIS (Moderate Resolution Imaging Spectroradiometer) image that was downloaded from: http://www.oceancolor.gfsc.nasa.gov in NetCDF (*Network Common Data Form*) format. The data, 4 km spatial resolution, were analyzed in SeaDAS 7.0.
3. Time series fish landing data from 2014 to 2016 were gathered from Pesawaran Regency fish market that were collected by Marine and Fisheries Resources Control Unit, Lampung. From these data, we obtained CPUE (Catch Per Unit Effort) data.

2.2. MODIS satellite images, chlorophyll-a and SST data

Chlorophyll-a and SST data from MODIS satellite image were level-3 data in NetCDF format which were resulted from Aqua and Terra satellite. These data, spatial distribution of chlorophyll-a and SST at Pesawaran waters, were extracted to get text file (.txt) using SeaDAS 7.0, and the mean of monthly climatologist from 2001 to 2016 were calculated and analyzed the correlation to other data.

2.3. Wind speed and direction

Wind data was collected from ECMWF in NetCDF format, and SeaDAS 7.0 was used to extract the data in research area on text file which were wind vector direction, u (west-east) and v (north-south). Then, from these data, we got total wind speed and direction that were plotted in wind rose to get the dominant direction.

3. Results and discussions

3.1. Monsoon influences to aquatic productivity and SST

The variability of aquatic productivity at Pesawaran areas correlated to monsoon, wind speed and wind direction. There was two peaks of wind speed that occurs in different period. In first period, maximum wind speed was occurred from December to March. In second period, it was occurred from August to October (Figure 2). Increasing in wind speed influenced the productivity of waters which can be seen from strengthening of chlorophyll-a and SST in west and east season. The peak of increasing chlorophyll-a concentration and lowest level of SST was happened collectively with maximum wind speed in January, February, August, or September (Figure 2 and Figure 3).

Maximum wind speed at Pesawaran waters was occurred twice which were in January about 2.55 m/s and September about 2.44 m/s, but minimum wind speed was occurred in April and November about 1.4 m/s and 1.7 m/s respectively (Figure 2). Also, maximum chlorophyll-a concentration was occurred twice which were in February about 0.74 mg/m^3 and in August about 0.78 mg/m^3, but the minimum was occurred in December and May about 0.44 mg/m^3 and 0.46 mg/m^3 respectively (Figure 4).

According to the explanation before, primary productivity based on chlorophyll-a concentration at Pesawaran waters in east season is higher than in west season. It is expected because of two factors. Firstly, it is caused by mixing processes that increase along with wind speed becoming greater, and it was also stated by [12]. This is in accordance with the research [13] which explained that winds and surface chlorophyll-a had high correlation in shallow mixed layer. Secondly, it is correlated with waters turbidity which is higher in east season than west season, so light intensity goes through the waters more frequently [14]. Thirdly, there is an upwelling phenomenon from the southeast Pesawaran waters centred in the west coast of South Lampung Regency (Figure 6) explained that limiting factor

bounding primary productivity was the light intensity that must be sufficed. In east season light intensity through Pesawaran waters is higher than in west season. Consequently, it caused photosynthesis processes more optimum in east season, so chlorophyll-a intensity in that season higher than another season. The correlation between wind speed and chlorophyll-a showed value of 0.48, and it explained that monsoon variability intercorrelated to chlorophyll-a variability in moderate category.

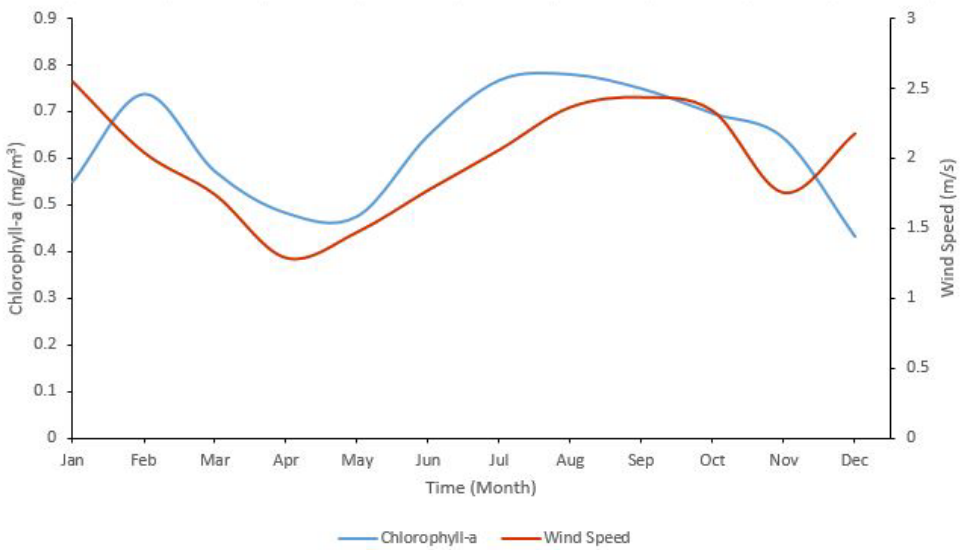

Figure 2. The average variability of wind speed in m/s and chlorophyll-a in mg/m^3 at Pesawaran waters from 2014 to 2016.

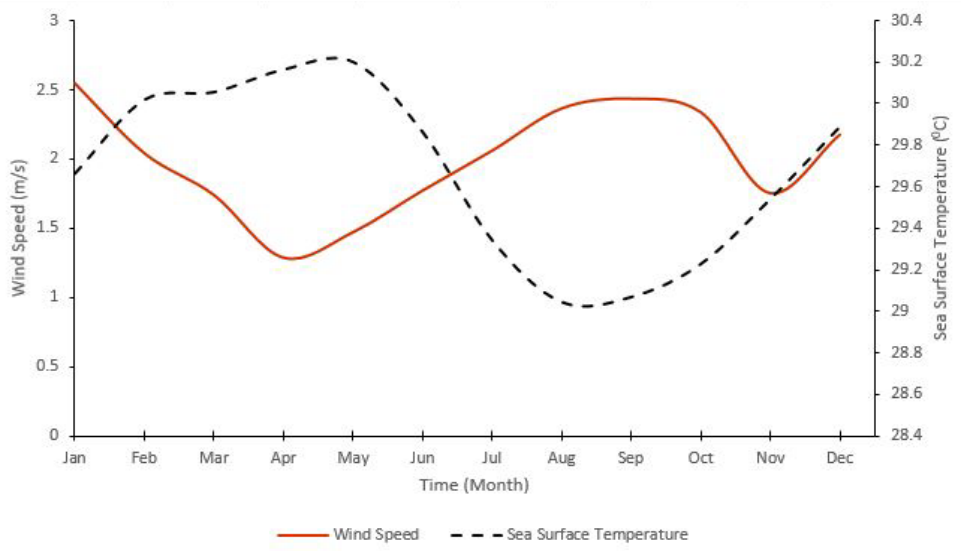

Figure 3. The average variability of wind speed in m/s and SST in ^{0}C at Pesawaran waters between 2014 and 2016.

In spite of increasing the aquatic productivity, monsoon also influencing SST [15] [16] [17], in this research, the monsoon decreased SST. Figure 3 shows that SST and wind speed have opposite correlations. In other word, maximum peak of wind speed is equal to minimum peak of SST. The lowest SST was happened in west season around January and in east season around September. Cold SST in west and east seasons are considered due to three factors. Firstly, it is the mixing processes that occur due to the increase of wind speed, so there is mixing process between cool water mass in the lower layer and hot water in the upper layer and it also described by [12] and [18]. Secondly, strong

wind speed makes the water surface disturbed [19]. Unsteady sea surface reduces the process of penetrating sunlight into the waters, which consequently reduce water temperature. On the contrary, increased temperatures occur when the water level is calm as the penetration of sunlight into the water column increases [20]. Finally, increasing in wind speed is expected by improving the advection process (heat-to-air release) and evaporation processes that also releasing heat from the water column and this is also argued by [21]. The correlation between wind speed and SST shows a value of -0.74, so it proof that wind variability strongly influences the variability of SST in the opposite relationship.

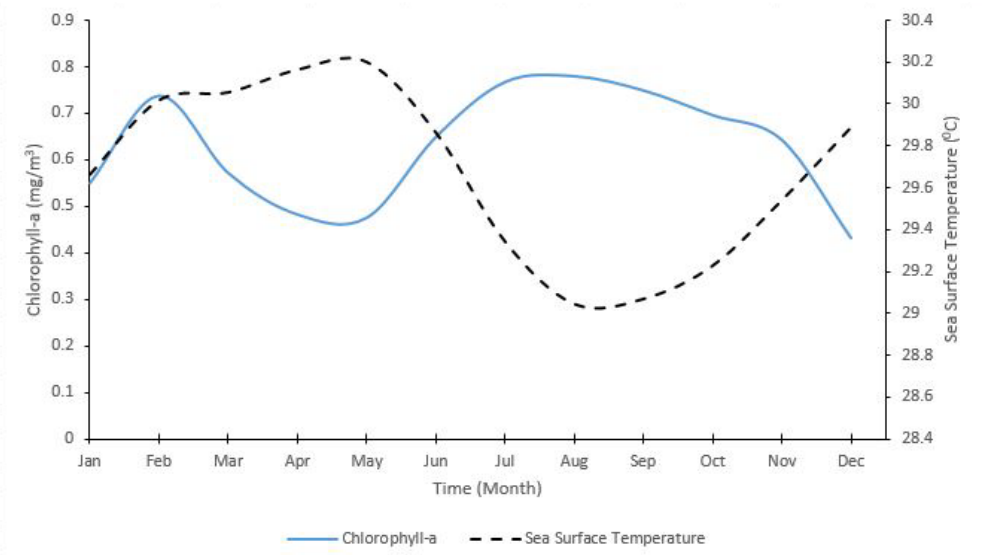

Figure 4. The average variability of chlorophyll-a and SST at Pesawaran waters between 2014 and 2016.

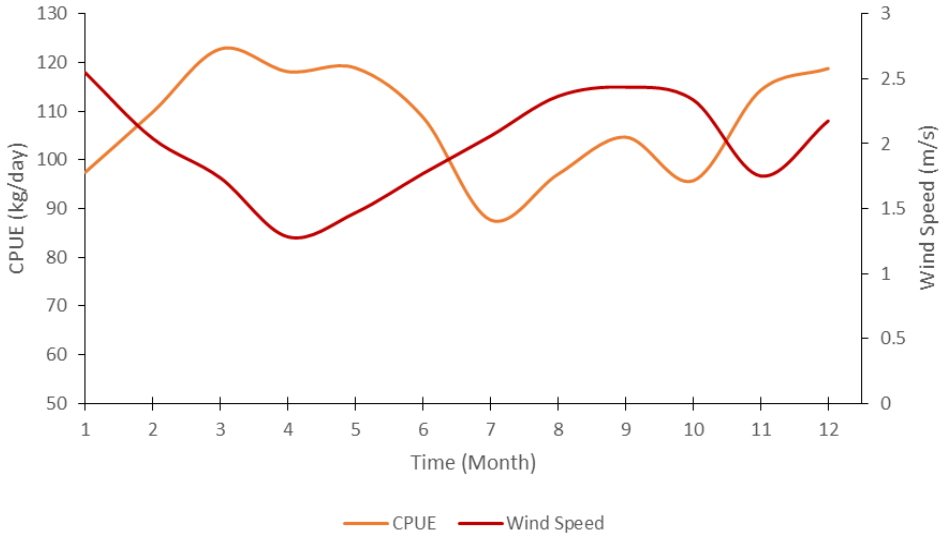

Figure 5. The average variability of wind speed from 2014 to 2016 and CPUE from 2014 to 2015 at Pesawaran waters.

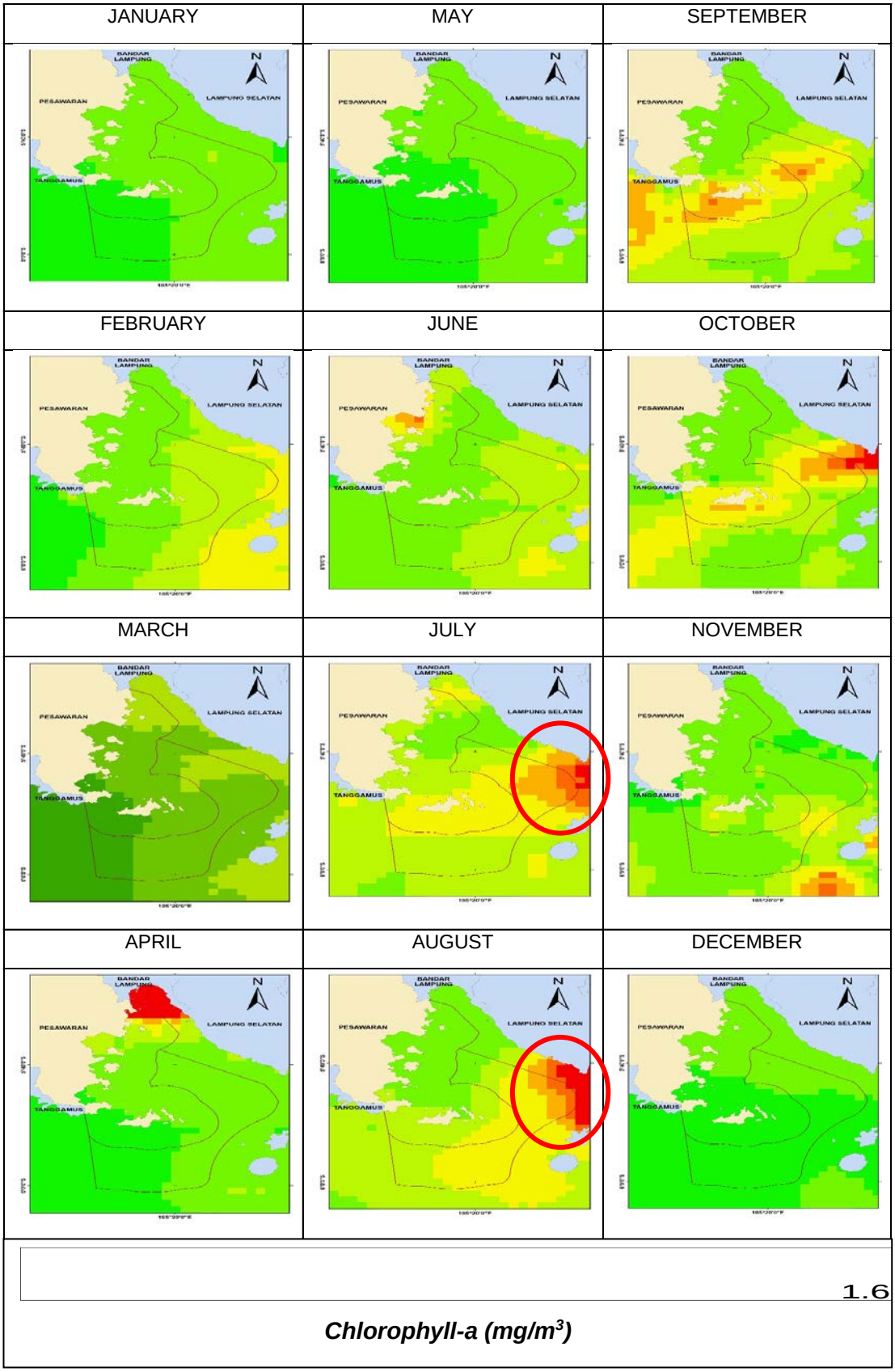

Figure 6. Monthly chlorophyll-a distribution (mg/m^3) at Pesawaran Regency Waters from 2002 to 2016, circled red is considered to be an upwelling centre.

3.2. Monsoon influences to fisheries productivity

The influence of monsoon variability is not only on the increase of aquatic productivity, but also on fishery productivity. Strong wind variability associated with SST variability further affects the productivity of fisheries. The wind velocity and chlorophyll-a concentration show the inverse relationship with the CPUE (Figure 5 and Figure 7), whereas the SST with CPUE shows a proportional relationship (Figure 8 and Figure 9). Figure 9 show that positive coherence between SST and CPUE (indicator the direction of the arrow to the right) very strong at the coherence value 0.8-1.0 in the 9th to 12th months. In general, there is lag times about 2 months between the peak of temperature and the peak of CPUE. The linkage can be seen when high wind speeds and low temperatures then the fishing results decreased. Meanwhile, when the wind speed is low and high temperatures then the fish catch increases. The correlation between temperature, wind, chlorophyll-a and CPUE can be categorized as strong including the correlation between wind and CPUE shows the value of -0.67. The correlation between SST and CPUE shows a value of 0.76, while the correlation between chlorophyll-a and CPUE shows a value of -0.70. The association of SST with CPUE is of course limited to the limits of fish tolerance that are subjected to capture.

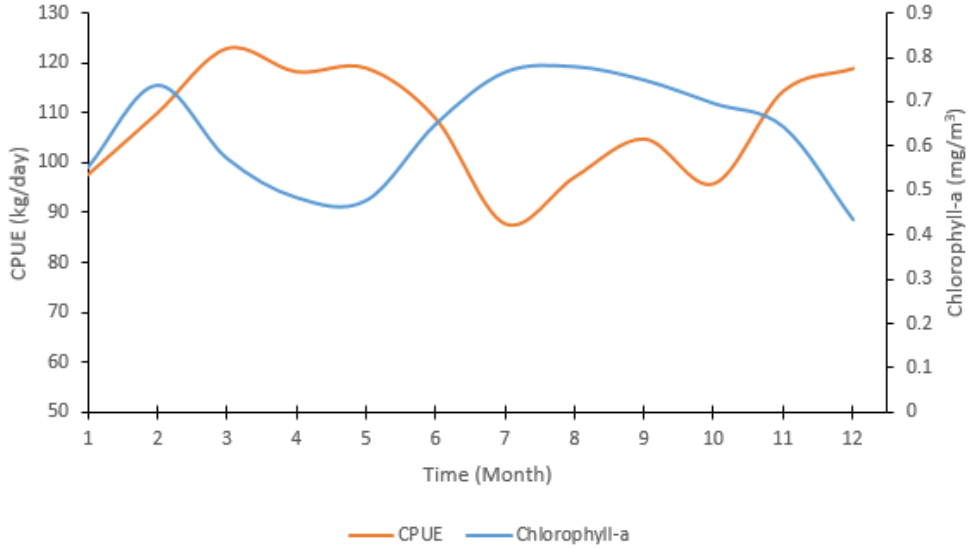

Figure 7. The average variability of chlorophyll-a from 2014 to 2016 and CPUE from 2014 to 2015 at Pesawaran waters.

Reduced wind velocity and increased SST associated with increased CPUE, in [22] SST had significant correlation to albacore CPUE, allegedly related to the optimization of the catching process by purse seine fishing gear and character of the fish target that favored warm waters. When the wind speed is weak in the waters in a calm condition, many fishermen get the process of catching with purse seine fishing gear. Purse seine fishing gear is assisted by light to attract the attention of the fish. When the condition of calm waters is expected to light into the waters become optimum that will attract fish, so that results more fish catches. Water temperatures that tend to be warmer when the wind speed is weak is presumably still within the optimum temperature tolerance. The dominant of fish caught in Pesawaran waters is mainly tuna, skipjack, shrimp, needle fishes and swordfish. These kind of fish have optimum temperature ranges from 29-30 ^{0}C which is in accordance with the Pesawaran water. The optimum temperature range for fish, especially small pelagic ranges from 29-30 ^{0}C [20].

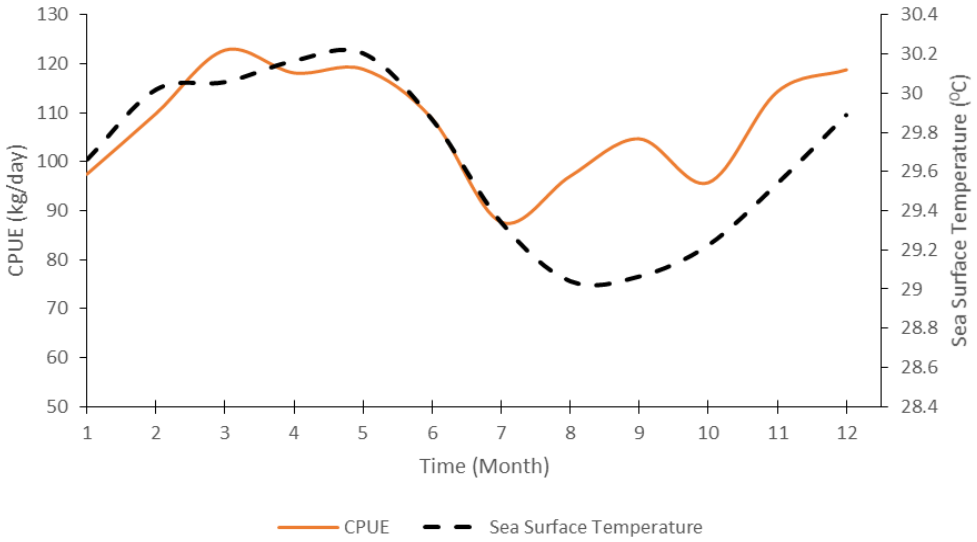

Figure 8. Average SST variations from 2014 to 2016 and CPUE from 2014 to 2015 at Pesawaran waters.

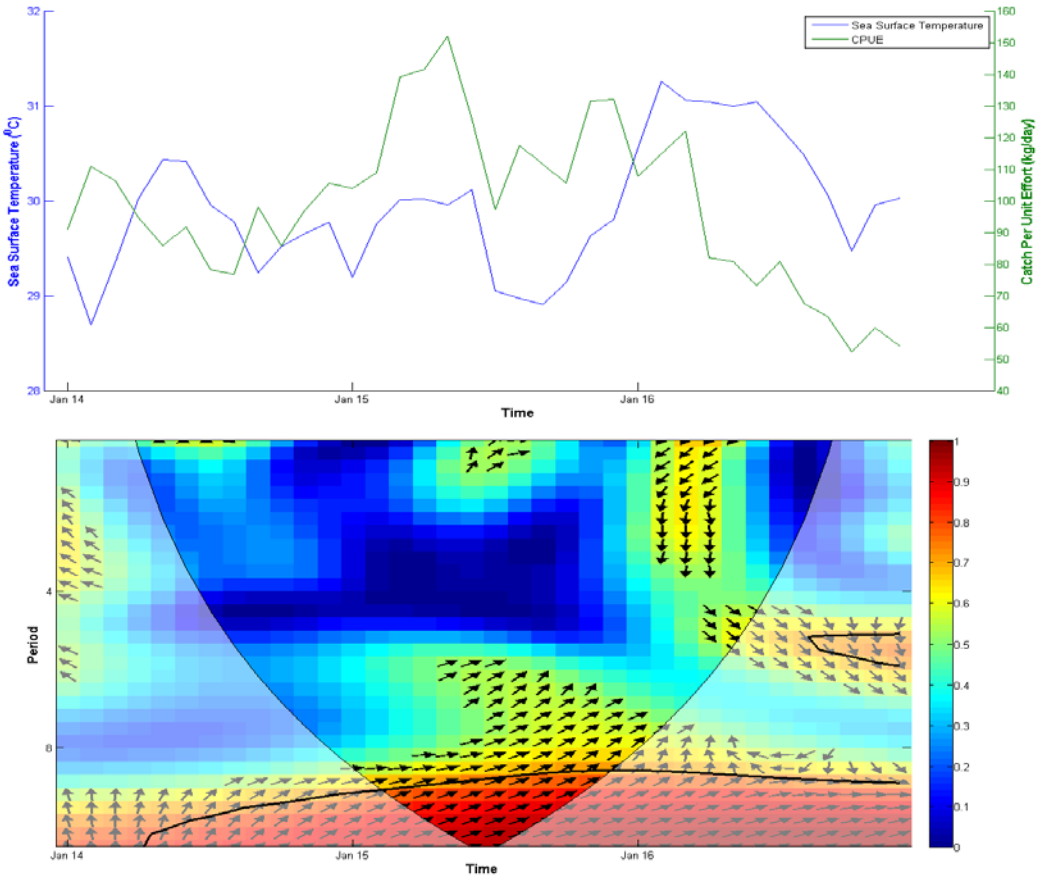

Figure 9. Coherence between SST and CPUE, show that coherence very strong with value of 0.8-1.0 in the 9 - 12 months, and there were lag times about 2 months between the temperature peak and the CPUE peak

Fishing season in Pesawaran waters generally occurs in March-May and October-December. The peak of the catches occurred in May and December (Figure 5). The highest catches occur to coincide with the maximum SST and minimum wind speed (Figure 5 and Figure 7). Increasing aquatic productivity in west season (the highest season) either in January or February and in east season occurred either in July or August are followed by increasing of fisheries productivity in 1 – 4 months after the highest peak of chlorophyll-a (Figure 6). This finding was unexpected and suggest that fish season at Pesawaran waters generally occur in 1 – 4 months after the highest peak of chlorophyll-a both in transitional season I (March-May) and transitional season II-West (September-December). As a result, the highest fish season occur in March and December. The fish season found is almost the same as that found by [21] in the Java sea.

4. Conclusions

Monsoon variability, that is wind speed and direction, effect on productivity, SST and fish catches at Pesawaran Lampung waters. Strong winds and cold SST occur twice a year, from December to March and from August to October, the peak is in January (wind speed 2.55 m/s, SST 29.66 ^{0}C) and September (wind speed 2.44 m/s, SST 29.06 ^{0}C). High productivity in Pesawaran waters also occurs two times a year with almost the same time with strong wind speeds, ranging from January to March and July to September, peak around February (0.74 mg/m^3) and August (0.78 mg/m^3).

The variability of fish catches based on landing data at Pesawaran waters appears to be more closely related to wind and SST variability than with aquatic productivity, when strong winds and low catchments of fish catches decreased, and when winds were weak and high catchments of fish catches increased. The measured temperature range is presumed to be within the optimum tolerance range of catch fish in Pesawaran waters. Correlation (r) between CPUE fish with SST, wind, and chlorophyll-a were at value 0.76, -0.67, and -0.70, respectively. Fishing season in Pesawaran waters generally occurs in March-May and September-December and the peak of fishing season generally occurs in March and December coincides with the hottest SST and the weakest wind speed.

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