The effect of monsoon variability on fish landing in the Sadeng Fishing Port of Yogyakarta, Indonesia

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Abstract. The volume of landing fish of the Sadeng Fishing Port within certain months showed an increase from year to year, especially during June, July and August (JJA). While in other months the fish production was low. The purpose of this research was to understand the influence of monsoon variability on fish landing in the Sadeng Fishing Port. Data were analyzed descriptively as spatial and temporal catch. Data were namely catch fish production collected from fishing port, while satellite and HYCOM model during 2011–2012 period were selected. The wind data, sea surface temperature (SST) and chlorophyll-a were analyzed from ASCAT and MODIS sensors during the Southeast Monsoon. The result showed the wind from the southeasterly provide wind stress at sea level and caused Ekman Transport to move away water mass from the sea shore. The lost water mass in the ocean surface was replaced by cold water from deeper layer which was rich in nutrients. The distribution of chlorophyll-a during the Southeast Monsoon was relatively higher in the southern coast of Java than during the Northwest monsoon. The SST showed approximately 25.3 °C. The abundance of nutrients indicated by the distribution of chlorophyll-a around the coast during the Southeast Monsoon, will enhance the arrival of larger fish. Thus, it can be understood that during June, July, and August the catch production is higher than the other months.

1. Introduction

The majority of seafood production, especially the catch fish is usually found in the tropics area between 10 °N and 10 °S [1]. Indonesian territory extends from 90-141 °E. This area is an important area for the productivity of tropical seafood. Natural fish stock from the Indonesian waters including the Exclusive Economic Zone (EEZ) is estimated around 6.4 million tons/year, with 63.5 % captured annually which consists of 4.14 million tons from the Indonesian Seas and 1.26 million tons from the Indonesia EEZ [2]. Pelagic fish plays an important role for the fishermen economy in Indonesia, i.e. about 75 % of the total fish stock or 4.8 million tons/year are pelagic fishes [3].

Due to the unique position of the Indonesia territory, Indonesia experienced a strong response to large climate phenomenon like the Australia-Indonesian Monsoon (AIM) and El Niño-Southern Oscillation (ENSO). The AIM and ENSO, as well as the interplaying phenomena between these two, are influenced by ocean-atmosphere interaction in the Pacific and Indian Oceans. Indonesia plays an important role in the global thermohaline cycle and global climate circulation, and also as the center of biodiversity, especially fish resources [4]. Other phenomena that may affect ocean color have been studied in Indonesian seas are ENSO, IOD [5, 6, 7], MJO [8], Waves and also the current of Kelvin and Rossby [9, 10,11]. All these ocean-atmosphere interactions affect the variability of SST, sea level anomalies, wind, and ocean color.
The Indonesian Seas are the only seas in the planet that connected two major oceans i.e the Pacific Ocean and Indian Ocean. This connection is known as Indonesian Throughflow (ITF) [12, 13]. Due to the coastal geographic influence and topographic variation of the ocean floor, the ITF variability is thought to be related to the marine color variability. Besides ITF, the ocean color in the Indonesian seas is strongly influenced by the AIM. During the Northwest Monsoon (December–February: DJF), river runoff may also affect the ocean color, not only through the delivery of the nutrients but also through the increase of particulate matter and colored dissolved organic matter (CDOM), especially in western Indonesia [3, 14].

Monsoon is a reversal of seasonal wind patterns caused by temperature gradients between land and sea [15]. Monsoon winds play an important role in generating currents, waves and SST. During the Southeast Monsoon season, the southeasterly winds from Australia generated upwelling along the southern coasts of Sumatra, Java, and Nusa Tenggara Island Chain [13]. The reverse condition occurred during the Northwest Monsoon season. An understanding of the spatial and temporal evolution of upwelling is an important factor in coastal fisheries. According to [16] an area falls into the category of a monsoon region if: 1) a major wind direction shifted at least 120° between January and July, 2) persistent wind direction at least 40% of the time in January and July, 3) Average windspeed over 3 m/s in January or July, 4) fewer than one cyclone-anticyclone change every 2 years in January or July.

Sea surface dynamics induced by monsoon winds have strong correlation with fish behavior and seasonal abundance and distribution of fishes. The study of marine processes in the Indonesian Seas, especially in the southern sea of Java can help fisheries community to estimate fish stock. A research on seasonal variability of pelagic fish production and processes that played important role in the sea around Java Sea has conducted [3]. Using over 20 years of fish catch data collected from several fish ports and ocean color data of 7 years, and the annual catch pattern was determined by monsoon activity [3]. Therefore, monsoon greatly influenced the emergence of warm and nutrient-rich surface currents in the Java Sea, surface water transport and upwelling in the Sunda Strait, the southern sea of Java which starts from the Bali Strait. Processes in different seas for each region greatly affected the fish distribution and catches.

The purpose of this research is to investigate the influence of monsoon variability on the catch production in Sadeng. In this study, the ocean color will be expressed as chlorophyll-a.

2. Materials and Methods

2.1. Study area

The study area in Sadeng, as shown in figure 1. Sadeng is a fishery port located in the Sadeng Bay, flanked by two villages namely Songbanyu and Pucung Villages. The distance from the provincial capital is about 85 km. The Sadeng Fishery Port is one of the work units of the regional technical implementation unit and is the headquarters of the regional fishery port which has work area along the coast of Yogyakarta. As a center for economic activities, the Sadeng Fishery Port is a gathering place for fishermen, fish traders, fishery entrepreneurs and other business entities that support economic activities in Sadeng, Songbonyu and Girisubo.
2.2 Data Collection
SST and ocean color data used in this research were obtained from MODIS. The data were processed using a python script or SeaDAS software that can be obtained from http://oceancolor.gsfc.nasa.gov/seadas/. The MODIS sensor detects the emitted and reflected radian in 36 channels which sweep the visible spectrum up to the infrared spectrum. More information related to the instruments can be obtained from NASA MODIS webpage (http://modis.gsfc.nasa.gov/about/specifications.php). Wind data were obtained from the ASCAT (Advanced Scatterometer) sensor on the METOP-A satellite and can be downloaded from http://manati.star.nesdis.noaa.gov/datasets/ASCATData.php/. The marine model data were obtained from HYCOM+NCODE and can be downloaded from http://tds.hycom.org/thredds/catalog.xml. Fish production data were obtained from Sadeng.

Table 1. Development of Sadeng PPP Production 2010-2014. (Source: UPTD PPP DKP Daerah Istimewa Yogyakarta, 2015).

| Year | Production (kg) | Production Value (IDR) |
|------|----------------|------------------------|
| 2009 | 1,639,000      | 13,620,186,000         |
| 2010 | 1,430,000      | 11,904,152,000         |
| 2011 | 961,170        | 10,896,980,000         |
| 2012 | 993,460        | 13,967,523,000         |
| 2013 | 914,490        | 13,073,328,500         |
| 2014 | 3,563,490      | 20,947,587,200         |

2.3 Data analysis
Daily SST and chlorophyll-a data for period of 2011–2012 were composed into monthly data using IDV (Integrated Data Viewer) software. The monthly composite images were then overlaid with sea surface wind.

3. Results and Discussion

3.1 Results
The result showed that during JJA, the upwelling firstly appeared in the southern Bali with low SST migrating westward towards the southern coast of West Java, as shown in figure 2. The migration path
depends on the seasonal evolution of the wind. The upwelling diminished due to a wind reversal associated with the emergence of the Northwest Monsoon (DJF) and the propagation of the Indian Ocean’s Kelvin wave. The interannual variability of upwelling in the southern Java is associated with ENSO. During El Niño, the upwelling of Java-Sumatra extends to near the equator and lasts longer until November.

Figure 2. SST and ASCAT streamline. (a) June 2011; (b) July 2011; (c) August 2011; (d) December 2011; (e) January 2012; (f) February 2012.
The intensity of upwelling is in line with the wind speed. It has been suggested that the upwelled water mass from the subsurface is rich in nutrients. This is indicated by the high concentration of chlorophyll-a as shown in figure 3.

**Figure 3.** Spatial patterns of chlorophyll-a superimposed with ASCAT wind. (a) June 2011; (b) July 2011; (c) August 2011; (d) December 2011; (e) January 2012; (f) February 2012.
The opposite condition occurs during DJF. The concentration of chlorophyll-a in the south of the Java is low which implies low fish catch. This condition is due to the wind blows toward the beach and forms a vortex. As a result eddies formed and endangered the fishermen.

If we plot the variability of SST and chlorophyll-a, it clearly seen that the variability of both parameters follows the monsoon variability, as shown in figure 4. The low SST coincides with the higher chlorophyll-a concentration that occurs during JJA. Similarly, the higher SST corresponds to the lower chlorophyll-a concentration.

![Figure 4. Temporal variability of SST and chlorophyll-a.](image)

The results of HYCOM model are shown in figures 5 and 6 respectively for JJA and DJF included with a cross-section of the coastline around Sadeng, Yogyakarta offshore as far as 780 km (indicated by line + --------■) in figures 5 and 6. In June the model was unable to capture upwelling. Thus no visible appearance of cold water pools on the surface and cross sections showed that the thermocline layer was at an average depth of 60 m around the coast. In July and August, the model shows the emergence of cold water pools that originated in the southern Bali that spread westward towards the Sunda Strait. From the cross section, it can be seen that the thermocline layer moves upward approaching the sea surface. Model also shows that the upwelling intensively take place in the southern Java during JJA.
Figure 5. SST and sea surface current from the HYCOM model (a, b, c) and cross-section of ocean temperature (d, e, f) from the coastline (0) to 780 km offshore during JJA. (a, b) June 2011; (c, d) July 2011; (e, f) August 2011.

During the Northwest Monsoon, the SST is relatively high (> 26.3 °C) and the thermocline layer is relatively deep about 60 m as shown in figure 6.
Figure 6. SST and sea surface current (a, b, c) and the monthly mean ocean temperature (d, e, f) of DJF. (a, b) December 2011; (c, d) January 2012; (e, f) February 2012.

3.2 Discussion
SST is an important indicator for coastal upwelling event. Cooler SST than the surrounding area is indicated by the coastal upwelling processes through the uplifting of the cooler water mass from the deeper layer to the surface. Monsoon wind can generate current, wave and wind stress. During JJA southeasterly winds interact with sea levels through wind stress will generate Ekman transport. Since
the location of the southern sea of Java is in the south of the equator, the direction of Ekman transport will move away from the Java coast to the ocean. The mechanism is shown in figure 7.

![Figure 7. The mechanism of Ekman transport in the southern sea of Java.](image)

Due to the Ekman's transport, there is a vacuum of water masses around the coast. The water is then replaced by the water mass from deeper layer with a cooler temperature of 25.3 °C than that in the surface. This water mass is rich in nutrients and is important for the marine food web. The occurrence of coastal upwelling and the higher of chlorophyll-a in the southern Java during JJA is in a good agreement with the increased of fish landing in the region (figure 8 and figure 9).

![Figure 8. The montly fishcatch data from 2005–2009 [17].](image)

There were interesting things happened in 2010, as shown in figure 9. The production of the catch is relatively higher in other months. 2009/2010 is the year of El Niño, it is anticipated that the annual upwelling variability across the coasts of Java and Sumatra is coupled to ENSO through ocean-atmosphere teleconnection [12]. The mutually reinforcing process between ENSO and AIM can generate a more intensive upwelling process and increase the abundance of chlorophyll-a around the southern coast of Java.
4. Conclusions
The influence of Southeast and Northwest monsoons on the variability of SST and chlorophyll-a have been discussed in the present study. During JJA, the SST in the southern coast of Java was relatively low (25.3 °C) compared to adjacent sea (26.32 °C). The concentration of chlorophyll-a during this period is relatively high compared to DJF. This phenomenon is a result of the coastal upwelling caused by the Ekman transport that is triggered by the wind stress. Furthermore, our results show that higher fish catch is observed during the upwelling season.

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