Distribution and oceanography characteristic of light fishing in the Java Sea

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Abstract. Light fishing location obtained from visible infrared imaging radiometer suite (VIIRS) boat detection (VBD) and satellite-based oceanographic data of chlorophyll-a concentration (chl-a), sea-surface temperature (SST), salinity, and sea-surface height (SSH) were used to evaluate the distribution and characteristic of oceanographic conditions on the light fishing location in the Java Sea. The objectives of this study were to monitor the distribution of light fishing vessels from VBD and to evaluate the oceanographic characteristic on light fishing position. VBD data were prepared by national oceanic and atmospheric administration website and oceanographic data was provided by ocean color and copernicus marine environment monitoring service website. Overlaid process between light fishing position and oceanographic data was used to extract the oceanographic value in the light fishing location. The result showed most of light fishing occurred during southeast monsoon. In general, most of light fishing appeared in position of 107–114°E and 4–5.30°S. In addition, light fishing located in oceanographic condition for SST of 28.1–31.1°C, chl-a of 0.26–0.60 mg/m³, salinity of 32–35.5 psu and SSH of 0.5–0.62 m. The VBD data opens up a number of potential future applications for more computable fisheries data analysis.

1. Introduction
Java Sea has a significant contribution to Indonesian fishery productions. Most of the fishing vessels operating in the Java Sea are purse seine and bouke-ami which use lights to attract fish. Fisheries statistics show that there were thousands of purse seine vessels operating in the Java Sea. In addition, several studies have shown that fisheries in the Java Sea are over fishing [1,2].

Lifting nets (bouke-ami), purse seine and hand lines using light as fish aggregation devices (FADs) [3,4,5]. Artificial light can affect fish behavior. In general, fish are attracted to artificial light [6,7,8]. Fish groups have a positive response to light by gathering and moving towards the light source [9]. The gathering of fish towards the light source is thought to avoid predators and forage for food, so that this behavior can be used to increase fish catch during fishing operations [9,10]. The light will attract the attention of the fish so the fish are grouped and easy to catch.

Conventionally, monitoring fishing vessels operating in the sea is difficult. This is because the sea is a very large area. Currently, systems and technologies have been developed that can monitor the lights on fishing vessels. With this technology, vessels monitoring will be more effective and efficient because it is able to reach a wide area in a relatively short time. In 2011, the Suomi National Polar Partnership (SNPP) satellite was launched with the main sensor the Visible Infrared Imaging...
Radiometer Suite (VIIRS). The VIIRS sensor has a Day / Night Band (DNB) sensor that can be used to detect lights installed on fishing boats that are conducting fishing operations at night. This sensor was designed to detect visible to infrared light at low or high intensity at a wavelength of 500 to 900 nm [11]. In addition, [12] have developed an algorithm for detection of light fishing vessels.

Different studies can be conducted using nighttime imaging data such as light emission mapping in marine protected areas (MPAs) [13,14] offshore drilling mapping [15,16], vessel detection and tracking [17,18], mapping of fish resource ecosystems [19], estimating fishing effort and intensity for single fish species [20], and mapping predictions of future fishing areas [21,22,23].

Distribution of marine biota, including fishes, is believed affected by changes in the environmental condition. For instance, [24] reported that squid assemblies most commonly in shallow waters, where SST vary from 8 °C to 24 °C with a low concentration of chlorophyll-a and less turbid water. In addition, [25] showed that most of Bigeye tuna assemble most frequently in SSH anomaly value of ranging from -21 to 5 cm, for SST ranging from 24° to 27.5°C, and for chl-a levels ranging from 0.04 to 0.16 mg m⁻³. Therefore, the goals of this analysis are to monitor the distribution of light fishing vessels from VBD and to evaluate the oceanographic characteristic on light fishing position.

2. Material and Methods

This research was conducted in the Java Sea in position of 03 °LS – 07 °LS and 105 °BT – 116 °BT (Figure 1). The Java Sea is the region for fisheries management of the Republic of Indonesia 712 (WPP RI 712).

2.1. Detection of light fishing from VBD

VBD data was used to determine the position of light fishing at night. Daily VBD data from 2016 through 2019, then converted to monthly and filtering was done using the quality flag (QF). The quality flag is the value used to detect the quality of the reflection received by the VBD sensor. In this study, QF1 is used to select the light fishing position. QF1 has a strong detection quality in predicting the position of light fishing with a SHI value of > 0.75 [12]. Light fishing was then assumed to be the position of a fishing vessel that uses buoke ami and purse seine as its fishing gear [26]. The data was downloaded from website https://www.class.ngdc.noaa.gov/eog/viirs/download_boat.html SNPP VIIRS day night band.

2.2. Satellite-derived environment variable
Monthly data of salinity and SSH were obtained from Copernicus Marine Environment Monitoring Service (CMEMS) website (www.cmems.co.id). Monthly data of SST and chl-a are obtained from the ocean color website (www.oceancolor.gsfc.nasa.gov). All the oceanographic data has a resolution of 9 km, from 2016 through 2019. The data was processed using SeaDAS 7.5.1 and Arcgis 10.4 Software. The overlaid methods was then used to extract the oceanographic value at light fishing location.

3. **Results and Discussion**

3.1. *Fishing vessels’s type*

Based on the field survey at Nusantara Fishery Ports (PPN) in Rembang, Pekalongan, Cirebon and Jepara [26] reported that most of the fishing vessels that use lighting aids for fishing are buoke ami (lift nets) and purse seine vessels. In addition, they also reported that the main catch of buoke ami is squid and is mostly found in Cirebon while purse seines for catching small pelagic fish are mostly found in Pekalongan, Jepara and Rembang. Fishing operations are carried out at night. The purse seine and buoke ami use lights as a tool to attract fish to come closer to the fishing vessels. This makes it easier to catch the fish. The number of lights installed on the buoke ami vessels was between 32-64 lamps with a power of 1500-200 watts while the lamps on the purse seine range from 10-25 lamps.

3.2. *Number and spatio temporal distribution of light fishing*

We used light fishing position and oceanography data to evaluate the distribution and oceanographic characteristics on the light fishing position. Analysis of VBD data helped us to locate the lights fishing through space and time. Figure 1 showed the number of light fishing during 4 (four) different season. In general, the number of light fishing in the western season was the least compared to the other 3 seasons. In contrast, the number of light fishing during eastern season was the most compared to the other 3 seasons. In contrast, the number of light fishing during eastern season was the most compared to the other 3 seasons.

Figure 2. Number of light fishing in the Java Sea during four different seasons from 2016 through 2019.

Figure 3 showed the distribution of light fishing in the Java Sea from 2016 through 2019. As the season that has the largest number of light fishing, the light fishing in the eastern season cover almost the entire study area (Figure 3b. C). During this season, most of the light fishing concentrated in the north of study area, close to Borneo Island. This condition consistent with the result of [11] who reported that the abundance of fish stocks in the southern waters of Borneo is greater than that of the north coast of Java. In addition, [27, 28] showed that fishing vessels that catching squids were concentrated in the same area.
Figure 3a. Light fishing (red dot) distribution in the Java Sea during west season (A) and transitional 1 season (B) from 2016 through 2019.
Figure 3b. Light fishing (red dot) distribution in the Java Sea during east season (C) and transitional 2 season (D) from 2016 through 2019.

In the transitional season and the east season, the number of vessels tends to be high and tends to be low in the west season. This result was consistent with the previous studies where the number of...
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...fishermen who go to the water in the west season is less than the eastern season [29]. The low number of fishing vessels operating during the western season was due to several factors such as bad weather conditions. In this study, the results showed that SSH in the west season between 0.50 – 0.70 m while the SSH in east season was 0.49 – 0.69 m (Figure 4). This result was supported by [30] who reported that the significant wave height in the Java Sea is greater in the west monsoon between 0.44-1.183 m compared to the east monsoon between 0.35-1.06 m. In addition, during the western season the fish population is less than east season in the Java Sea [31].

Figure 4 showed the fluctuation oceanographic condition in the study area during 4 years. During these 4 years the study area has SST value of 27 - 34.5°C with an average value of 29.71 °C. In general, the SST in the eastern monsoon was lower than the other seasons, with average value of 28.9 °C while the higher SST was occurred in transition 1 season with SST value average of 30.38 °C. The study area also has chl-α value of 0.09 - 4.99 mg/m³ with an average value of 0.67 mg/m³. The higher chl-α value occurred in east season with chl-α range value of 0.19 – 4.99 mg/m³, while the lowest value occurred in west season with chl-α range value 0.09 – 0.97 mg/m³. In addition, during the period, the study area has value salinity value of 30 - 34.7 PSU with an average value of 32.62 PSU and SSH value of 0.40 – 0.77 m with an average value of 0.575 m. 

![Figure 4a](image)

*Figure 4a.* The condition of four different oceanographic parameters from 2016 through 2019 during west season. The top line of the box shows the highest quartile, the middle line with an (●) indicates the median and the bottom line of the box shows the lowest quartile. The red color shows the outlier data.
Figure 4b. The condition of four different oceanographic parameters from 2016 through 2019 during transitional 1 season. The top line of the box shows the highest quartile, the middle line with an (•) indicates the median and the bottom line of the box shows the lowest quartile. The red color shows the outlier data.

Figure 4c. The condition of four different oceanographic parameters from 2016 through 2019 during east season. The top line of the box shows the highest quartile, the middle line with an (•) indicates the median and the bottom line of the box shows the lowest quartile. The red color shows the outlier data.
Figure 4d. The condition of four different oceanographic parameters from 2016 through 2019 during transitional 2 season. The top line of the box shows the highest quartile, the middle line with an (*) indicates the median and the bottom line of the box shows the lowest quartile. The red color shows the outlier data.

Productivity and distribution of fish is affected by alterations in the environmental situation from variety in temperature, tides, salinity, SSH, thermocline’s depth and wind fields [32, 33, 34]. Figure 5 showed the frequency of light fishing and the 4 oceanography factor. In this study, most of light fishing emerged in chl-a value of 0.2 – 0.5 mg/m³ (Figure 5A). Chl-a data is a reliable proxy for boundaries of water mass and upwelling events.

The characteristic SST for light fishing was shown in Figure 5B. Most of the light fishing located in SST value of 28 – 30 °C. Water temperatures have a significant impact on growth, behavior and mobility, migration and distribution of fish. Variety in water temperatures below optimal temperatures cause a decrease in movement and feeding activity and impede the spawning process [35].

Salinity is one of the seawater's physical environment which plays a role in marine organisms’ survival. The fish's salinity requirements are primarily for diffusion and osmosis. Changes in high salinity levels can cause a disturbance of the process that can cause death. Even salinity can serve as an indicator of the water mass enrichment process [36]. In addition, the differences in salinity are lower in offshore areas than in coastal areas. This is because the land is having a run-off impact [37]. In this study, most of light fishing appeared in salinity value of 32 – 33 psu (Figure 5C). We also used SSH to comprehend the characteristic oceanography for light fishing. The SSH was used to understand ocean instability, such as variations, eddies and current dynamics, that could be employed proxies for future fishing areas. In this study most of the light fishing appeared in SSH value of 0.5 – 0.6 m (Figure 5D).
Figure 5. Frequency (%) of light fishing and 4 parameter oceanography namely (A) chlorophyll-a, (B) sea surface temperature (C) salinity and (D) sea surface height, from 2016 through 2019.

4. Conclusion
Most of light fishing appeared in east season. During this season, the light fishing concentrated close to Borneo Island. Most of light fishing located in chl-a value of 0.2 – 0.5 mg/m³, SST value of 28 – 30 °C, salinity value of 32 – 33 psu and SSH value of 0.5 – 0.6 m.

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