Distribution of fishing vessels derived Visible Infrared Imaging Radiometer Suite (VIIRS) Sensor and Vessel Monitoring System (VMS) in the Java Sea

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Abstract. We analyzed the distribution of Purse seine fishing vessels using fishing lamps derived from the Day/Night Band Visible Infrared Imaging Radiometer Suite (DNB-VIIRS) sensor and Vessels Monitoring System (VMS) platform in the Java Sea. The data of fishing vessel distribution derived the DNB-VIIRS sensor and VMS platform was provided by NOAA Center for Environment Information and Global Fishing Watch respectively. The intensity of lights during the fishing operation was measured by a lux meter. The fishing vessel types that used light during fishing operations were small (<15 units lamps) and large vessels (>15-unit lamps). The intensity of light in the big vessels (>2,000 Lux) was higher than the small vessels (<2,000 Lux). The average number of fishing vessels operating during the Southeast monsoon were more than those of the Northwest monsoon. The distribution of fishing vessels derived from the DNB-VIIRS sensor has a similar pattern with the VMS platform. Generally, the fishing vessels are concentrated along the southern coast of Borneo but in the Northwest monsoon shift towards the northwest of Java approaching the island of Sumatra.

1. Introduction

Indonesia is a maritime country that has marine fishery resources of high potential. In 2016, the production of captured fisheries in Indonesia amounted to approximately 6.5 million metric tons and has increased in productivity from 6.5 million to 9.5 million tons in 2018. Now Indonesia has the 2nd largest fish capture production in the world; meanwhile, the aggregate maximum sustainable yield is estimated at 12.5 million metric tons per year. Therefore, the utilization of fishery resources in Indonesian waters can still be increased especially in eastern Indonesian waters [1].

Until now the practice of illegal fishing still occurs in Indonesian waters [2]. One obstacle in the monitoring of fishing vessels in the territorial waters of Indonesia is a limited budget to support patrol and other surveillance activities because Indonesian waters are very vast.

Another issue in Indonesian fishery capture is the decreasing tendency of fishermen's productivity in a particular area while in other areas the potential of fisheries has not been utilized optimally due to the distribution of fishing vessels being concentrated in particular waters such as in the Java Sea. For sustainable marine fishery management, the spatial and temporal monitoring of fishing vessels in Indonesian waters becomes necessary.

The conventional methods for monitoring fishing vessel distribution in Indonesian waters are ineffective and inefficient because their range is limited and their cost is high. Therefore, the
The development of new methods can be carried out by telemetry systems and satellite sensors. The satellite sensors which can be used to monitor fishing vessel distribution are Synthetic Aperture Radar (SAR) [3][4][5] and DNB-VIIRS sensors [6][7][8]. In 2017, Indonesian fisheries agency began to apply advanced technology to monitor fishing vessels in Indonesian waters through the use of a digital VMS in the form of the Global Fishing Watch (GFW) platform.

The VMS is used primarily for law enforcement purposes in fishery capture and also to provide information on the distribution of fishing vessel activities in Indonesian waters. The spatial and temporal data of fishing vessel activities derived from the VMS platform can be incorporated into ecosystem management plans to support sustainable fisheries in Indonesian waters [9][10][11][12].

Monitoring of fishing vessel distribution derived from DNB-VIIRS and SAR sensors is still rarely conducted in Indonesian waters. The assessment of the DNB-VIIRS sensor application for mapping the distribution of fishing vessels in Indonesian waters is still at an early stage. The first publication that was published in 2015 but until now there are only four publications that have been published [8][13][14][15].

The Government of Indonesia through the Ministry of Maritime Affairs and Fisheries has required fishing vessels larger than 30 GT to use the VMS system since 2017. Therefore, there is still a need to develop several methods for monitoring fishing vessels less than 30 GT. Monitoring of fishing vessels by combining several methods is expected to support the availability of fishing vessel data operating in Indonesian waters. The purpose of this study was to analyse the distribution of fishing vessels derived from DNB-VIIRS and VMS sensors in the Java Sea.

2. Methods

The study area (Figure 1) was located in the Java Sea. We used the VIIRS satellite, VMS and field survey data. The DNB-VIIRS satellite imageries were obtained from the National Oceanic and Atmospheric Administration (NOAA) website (https://ngdc.noaa.gov/eog/viirs/download_boat.html). The VMS data was obtained from the GFW website https://globalfishingwatch.org/initiatives/indonesia-vms/. A field survey for the identification of fishing vessel types were conducted in Cirebon, Pekalongan, Jepara and Rembang on 20–26 June 2018 and measurements of light intensity was conducted in Indramayu on 11–13 August 2019.

![Map of Java Sea](image)

**Figure 1.** Location of study in Java Sea and field data collection in Java Sea.
The distribution of fishing vessels data in the csv format derived from VIIRS DNB was processed based on the algorithm developed by Elvidge [8]. Based on the light intensity the types of fishing vessels were classified as strong detection with Quality Flag (QF1) and weak detection (QF2). Spatial mapping and analysis of the distribution of fishing vessels was conducted using geographic information system (GIS) software.

The spatial distribution of fishing vessels was analyzed using spatial indicators namely (1) spatial dispersion, and (2) directional dispersion [16]. The spatial dispersion of fishing vessels was calculated using a "standard distance tool" representing the degree to which spatial fishing vessels activity are spatially distributed around the central tendency. The greater of the circle radius value, the more dispersed the fishing activity or vice versa. Directional dispersion was calculated using the "standard deviational ellipses tool".

\[
SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i-x)^2}{n}} + \sqrt{\frac{\sum_{i=1}^{n}(y_i-y)^2}{n}}
\]

(1)

\[
SD_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i-x)^2}{n}} \quad SD_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i-y)^2}{n}}
\]

(2)

where \(SD\) is spatial dispersion, \(SD_x\) is directional dispersion of x axis and \(SD_y\) is directional dispersion of y axis.

The light intensity was measured using a digital Lux meter model AR-823 with the capacity of 0-100,000 Lux and an accuracy of 3%. Measurement of light intensity was conducted on fishing boats at sea.

3. Results and discussion

3.1. Types of fishing vessels and light intensity

Types of purse seine fishing vessels that used lights for fishing in Indramayu were purse seine and classified into big vessels (> 10 GT) and small vessels (<10 GT). The number of lamps used on the big vessels and small ones were 19 units and 11 units respectively. The intensity of lights around the big vessel and small vessel was 2000 Lux and 3500 Lux respectively.

![Figure 2. (a) The intensity of the light (a) around small vessel is 2000 Lux (b) big vessel is 3500 Lux.](image-url)
Based on the fishing vessels detection algorithm developed by Edvigde [8], the light intensity detected by the VIIRS DNB sensor was classified into two categories namely strong detection (QF1), and low detection (QF2). In accordance with field observations, the intensity of light during fishing activities could be also classified into high intensity (>2000 Lux) and low intensity (<2000 Lux).

### 3.2. Fishing vessel distribution

The number of fishing vessels (purse seine and lift net) detected from the DNB VIIRS sensor per day was fluctuating in the Java Sea (Figure 3). The daily average of vessels detected from sensors was 1,248 units. The lowest average ship was 259 units in June and the highest was 2,092 units in September.

In general, the number of vessels detected during the Southeast monsoon was higher than the Northeast monsoon. This situation due to the weather condition during the East monsoon was better than the Northwest monsoon. In addition, the fish population in the Java Sea during the Northwest monsoon was less than Southeast monsoon [17]. Previous studies show that the fishing season of Decapterus spp. and Rastrelliger kanagurta in the Java Sea were September and August respectively [18].

![Figure 3. The daily average of fishing vessels (Purse seine and lift net) in the Java Sea derived from the DNB-VIIRS sensor in the Java Sea.](image)

Figure 4 shows the distribution of fishing vessels detected by the DNB-VIIRS sensor in purple color while the light blue VMS platform and white color is VIIRS & VMS overlap. Fishing vessels distribution derived from DNB-VIIRS and VMS platform has a similar pattern forming an elliptical circle in the Java Sea (Figure 5). Generally, the fishing vessels were distributed near the coast of Java, Kalimantan and Sumatra, but were more concentrated in the southern coast of Kalimantan. Along the southern coast of Kalimantan large rivers flow carrying high nutrients into the Java Sea. These waters become fertile so that it becomes one of the factors causing fish to be concentrated around the coast.

In general, the number of ships detected by the VIIRS sensor is more than VMS because only ships larger than 30 GT are required to use VMS while vessels smaller than 30 GT are not required to use VMS. Indonesian fisheries statistics show that 90 percent of fishing vessels in Indonesia are dominated by vessels smaller than 5 GT. Thus, the data distribution of fishing vessels based on the VIIRS sensor becomes one of the sources of information to complement the data on fishing vessels operating in the Java Sea.
Figure 4. Distribution of fishing vessels derived from VMS and VIIRS data in the Java Sea in 2017.

Spatial analysis of fishing vessel distribution shows that the fishing vessels are more concentrated on the southern coast of Kalimantan, especially during the Southeast monsoon (Figure 5a); meanwhile the fishing vessels are more concentrated westward from the Java Sea approaching the coast of Sumatra in the Northwest monsoon (Figure 5b).

Table 1 show the seasonal values of geographic distribution of fishing vessels indicators namely center x, center y, directional dispersion, spatial dispersion and directional trends. The distribution center of fishing vessels in the Southeast monsoon is at 110.96°E and 04.74°S, while in the Northwest monsoon it is 110.83°E and 05.044°S. Spatial dispersion (circle) of fishing vessels in the Southeast monsoon is 298.9 km shorter than in the Southeast monsoon which is 315.1 km, indicating that the distribution of fishing vessels in the Northwest monsoon is wider than in the Southeast monsoon.
Figure 5. Spatial dispersion (circle) and direction of dispersion (ellipse) of fishing vessels in the Java Sea (a) in the Southeast monsoon, and (b) in the Northwest monsoon.

Table 1. The values of fishing vessels seasonal geographic distribution.

| Seasonal   | Center X  | Center Y  | Directional dispersion x (km) | Directional dispersion y (km) | Spatial dispersion (km) | Directional trends (°) |
|------------|-----------|-----------|--------------------------------|--------------------------------|-------------------------|------------------------|
| Southeast  | 110.96°   | -4.74°    | 377.26                         | 190.69                         | 298.91                  | 108                    |
| Northwest  | 110.83°   | -5.04°    | 404.28                         | 187.38                         | 315.08                  | 103                    |

4. Conclusions
The purse seine fishing vessels are classified into two classes with a number of lamps less than 15 units with low intensity (<2000 Lux) and a number of lights of more than 15 units (> 2000 Lux) with high intensity. The number of fishing vessels operating in the Southeast monsoon is higher than in the Northwest monsoon. The spatial distribution of fishing vessels derived from the DNB-VIIRS sensor has a similar pattern with the VMS platform. In the Southeast monsoon, the fishing vessels are generally concentrated along the southern coast of the island of Borneo but in the Northwest monsoon concentration shifts towards the northwest of Java approaching the island of Sumatra. The spatial distributions of fishing vessels in the Northwest monsoon is wider than in the Southeast monsoon.

5. References
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