Distribution of fishing boats and its oceanography characteristic in the eastern Indian Ocean off Sumatera

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Abstract. Understanding fishing boats locations and its oceanographic feature were significantly important. The objectives of this study were to characterize the dissemination of fishing boats and evaluate the characteristic of oceanographic conditions on the fishing boats in the eastern Indian Ocean of Sumatera (EIOS). The data of fishing boats derived vessel monitoring system (VMS) and visible infrared imaging radiometer suite (VIIRS) boat detection (VBD) data were provided by Ministry of Maritime Affairs (MMA). Satellite-based oceanographic data of chlorophyll-a concentration (chl-a), sea-surface temperature (SST), and salinity were obtained from NOAA national centers for environmental information website. The results showed the number of fishing vessel that operated during east monsoon was higher than others monsoon. The results also showed that the spatial dispersion of VBD data was wider than VMS data. Most of the fishing boats appeared in position of 95°E – 100°E and 2.30°S – 2.30°N. In addition, most of fishing boats detected in oceanographic condition for SST of 29 – 31 °C, chl-a of 0.1 – 0.3 mg/m³, salinity of 32 – 33 psu.

1. Introduction
The high level of fishing-vessel operation in the Indian Ocean has forced the government to control the distribution of vessels in order to support protection, safety and sustainability efforts in the fisheries sector. In addition, boat surveillance may also minimize illegal, unreported and unregulated (IUU) fishing practices, which could have negative effects, such as tension between fishermen and a reduction in state revenues and reduction in the availability of marine and fisheries resources [1]. One of the regions in the Indian Ocean that has a strategic fisheries area with significant maritime activity is Fish Management Area no. 572.

Currently, boat surveillance in Indonesian seas is carried out by boat patrols and the use of tracking devices such as the Vessel Monitoring System (VMS). The VMS was used to track the movement of vessels and provide information on the location, speed and direction of the vessel to the port [2, 3]. In addition, visible infrared imaging radiometer suite (viirs) boat detection (VBD) can be used to detect fishing boats. Many studies have employed VBD data to detect fishing vessels such as [4-7]. Integrating VDB data with VMS data, it would be possible to decide vessels that do not have or lost a VMS signal.

On the other hand, productivity and distribution of fish are affected by changes in environmental conditions due to variability in temperature, tides, salinity, wind patterns, thermocline depth and sea surface height [8, 9, 10]. Water temperatures have a major effect on fish growth, movement and mobility, migration and distribution. Changes in water temperatures below optimum temperatures cause
a decrease in movement and feeding activities and inhibit the spawning process [11]. Salinity may have an effect on the quality of seawater and species and the biota. Fish prefers to choose areas with salinity that was compatible with the osmotic pressure of the body. Chlorophyll-a concentration (chl-a) defines the availability of food for fish. Chl-a developed as a response to low water temperatures as an impact of the upwelling process. [12] reported that SST and chl-a were the most significant variables affecting CPUE sardine. The objectives of this study were to investigate the distribution of fishing boats and its oceanography characteristic.

2. Methods

2.1. Study area
The research was performed in the EIOS, ranging between 6°N – 9°S and 91°E – 106°E (Figure 1). This region is recognized as one of the fishing areas for tuna. EIOS is part of the fisheries management area of the Republic of Indonesia called WPP RI 572.

![Figure 1. Map of study area in the eastern Indian Ocean off Sumatera.](image)

2.2. Satellite-based data
We used data from VBD, VMS and satellite-derived oceanographic data. The VBD data was downloaded from National Oceanic and Atmospheric Administration (NOAA) website (https://www.ngdc.noaa.gov/eog/viirs/map_selector/). The VMS data was provided by Ministry of Maritime Affairs and Fisheries Indonesia (http://integrasi.djpt.kkp.go.id). Level 3 monthly data for SST and chl-a were obtained from oceancolor website (https://oceancolor.gsfc.nasa.gov/cgi/l3). Level 3 monthly for salinity was obtained from copernicus marine service website (www.cmems.co.id).

The dissemination of fishing boats data in csv format extracted from VIIRS DNB. The data was analyzed on the basis of the algorithm developed by [4]. Based on the light intensity, the types of fishing boats were classified as high quality flag (QF1) detection. The speed and fishing gear type of boats were employed as a gauge to decide the fishing boats from VMS. The boats speed less 3 knots was recognized operating fishing works while boats speed more than 3 knots were consider not to be operating fishing works. Spatial mapping and analysis of the dissemination of fishing boats and oceanographic data were carried out using the Geographic Information System (GIS) software.

The spatial dissemination of fishing boats has been studied using spatial indicators, namely (1) spatial dispersion and (2) directional dispersion. The spatial dispersion of fishing boats was measured using a "standard distance tool" reflecting the degree to which the behavior of the space fishing boats is spatially dispersed around the central pattern. The greater the value of the circle size, the more scattered the fishing activity, or vice versa. In addition, directional dispersion was measured using the "standard
deviation ellipses tool" which represents the direction of the coordinate distribution of boats in the x and y directions.

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

(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.

3. Result and Discussion

3.1. Number and distribution of fishing boats

The number of fishing boats extracted from VBD and VMS fluctuated in the EIOS (Figure 2). The fluctuation is thought to be due to the absence of signal from the VMS or because of cloud cover or bad weather so that it could not detect the light fishing from VBD. The fluctuated In general, the number of fishing boats collected from VMS was higher than the VBD. A total of 19451 VMS and 17710 VBD data were obtained from January 2017 – December 2018. In addition, the number of fishing boats extracted from VMS during west season and transitional was more than east season. The findings were consistent with those of [13] who demonstrated that the angling vessel was working during the southeast monsoon more than during the northeast monsoon. They also showed that the high predicted probability area of tuna occurred in west and transitional season.

Figure 3 showed the spatial dispersion (circle) and direction of dispersion (ellipse) of VBD and VMS. In general, circle and an elliptical of VBD and VMS has identical impression in 4 different season. However, the spatial dispersion and direction of dispersion of VBD was slightly more south and bigger than the dispersion and VMS’s direction of dispersion. This condition was indicated that the fishing boats extracted from VMS slightly concentrated in the north part of study compared with VBD. The intersection area between the VMS and VBD data was in position of 96 °E – 101 °E and 2.30 °N – 2.30 °S.

Table 1 showed the seasonal values of measures for the geographical dissemination of fishery vessels i. e. center X, center Y, directional dispersion, spatial dispersion and directional trends. The distribution centre of light fishing (VBD) in west season is at 100.0256 °E and 1.2956 °S, while in the east season is 100.6425°E and 1.8468°S. Spatial dispersion of it in the west season is 535.8600 km longer than in the east monsoon which is 496.9104 km, demonstrated that the dissemination of fishing boats in the west season is bigger than in the east season. Furthermore, the distribution center of fishing boats (VMS)
in west season is at 98.2268 °E and 0.2142 °S, while in the east season is 97.6535°E and 0.4307°N. Spatial dispersion of it in the west season is 348.1624 km slightly longer than in the east season which is 339.4899 km, expressed that the dissemination of fishing boats in the west season is slightly wider than in the east monsoon.

![Figure 3](image-url)

**Figure 3.** Spatial dispersion (circle) and direction of dispersion (ellipse) of fishing boats in the study area during the (a) west season, (b) transitional 1 for VBD and VMS, (c) east season and (d) transitional 2 for VBD and VMS.

**Table 1.** Values of angling vessels seasonally distributed geographically.

| Seasonal   | Center X (°) | Center Y (°) | Directional Dispersion x (km) | Directional Dispersion y (km) | Spatial Direction (km) | Directional Trends (°) |
|------------|--------------|--------------|------------------------------|------------------------------|------------------------|------------------------|
| **VBD**    |              |              |                              |                              |                        |                        |
| West       | 100.0256     | -1.2956      | 741.6118                     | 155.8968                     | 535.8600               | 136.7681               |
| Transitional I | 101.1282     | -2.5974      | 774.8447                     | 181.6738                     | 562.7564               | 135.9344               |
| East       | 100.6425     | -1.8468      | 686.5885                     | 149.7870                     | 496.9104               | 136.7662               |
| Transitional II | 101.2188    | -2.5098      | 853.9536                     | 146.6213                     | 612.6723               | 134.1847               |
| **VMS**    |              |              |                              |                              |                        |                        |
| West       | 98.2268      | -0.2142      | 470.5909                     | 144.8393                     | 348.1624               | 139.6882               |
| Transitional I | 97.7612     | 0.0369       | 474.1630                     | 145.7944                     | 350.7753               | 142.7657               |
| East       | 97.6535      | 0.4307       | 456.4788                     | 148.7747                     | 339.4899               | 142.8897               |
| Transitional II | 97.6925    | 0.5316       | 378.9123                     | 126.7085                     | 282.5151               | 138.3180               |
Figure 4 showed the oceanographic condition on the fishing boats. The figure showed that most of the fishing boats located in chl-α value of 0.1 – 0.2 mg/m³. [14] reported that most Yellowfin tuna (Thunnus albacares) in water around West Sumatera caught in chl-α value of 0.15 mg/m³ – 0.17 mg/m³. The Indian Ocean is one of the region most impacted by the El Niño events. Intense El Niño events in this area have a direct impact on primary production and may cause anomaly high chl-α [15]. Therefore, an environment with high concentrations of chlorophyll, such as upwelling areas with convergence zones for plankton aggregation, is likely to attract larger predators, such as tuna [16]. Such chl-α can result in increased catches during the El Niño case [17-20].

In this study, most of fishing boats detected in SST value of 29 – 31 °C. [21] stated that the highest CPUEs of Skipjack tuna are characterized by SST value of 28.5°C – 30°C. Temperatures were believed to have an influence on fish growth, behavior and mobility, migration and dissemination. Furthermore, salinity was another important abiotic factor that affects the physiology of fish and affects the ability of fish to survive in different environments. Salinity has a significant effect on the physiology (osmotic pressure) of marine animals, including tuna. [22] noted that the dissemination of Bigeye tuna is affected
by numerous oceanographic factors, including salinity. In addition, [23] estimated that the majority of Bigeye tuna distributed in the salinity value of 34 psu and high salinity will postpone the movement of Bigeye tuna. This study showed most of fishing boats appeared in salinity value of 32 – 33 psu.

4. Conclusion
Most of the fishing boats from VMS and VBD located in area of 95 °E – 100 °E and 2.30 °N – 2.30 °S. The fishing boats, both those originating from VBD and VMS, were appeared more frequently in chl-a value of 0.1 – 0.3 mg/m³, SST value of 29 – 31 °C and salinity value of 32 – 33 psu.

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