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HOT SPOTS ANALYSIS OF FISHING VESSELS IN ANAMBAS ISLANDS 2014 - 2020

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ABSTRACT

The Anambas Islands is one of the regencies in the administrative area of the Riau Islands Province. The sea waters of the Anambas Islands are one of the regions that are strategic in Indonesia because they are located in the South China Sea and bordered by Malaysia, Singapore, Vietnam, and Thailand. Understanding the location of hot spots of fishing activities in this area is very useful for knowing fishing areas as the basis for fisheries management, and potential fish stocks and distributions estimation. This study aims to determine the distribution of fishing vessels in the Anambas Islands, and the distribution of hot spots of fishing vessel locations in the Anambas Islands from 2014 to 2020. The method used is Optimized Hot Spot Analysis which runs the Hot Spot Analysis algorithm by calculating Getis-Ord Gi* statistics on each pixel of the fishing vessels detection image. The study found that the Tokongnanas hot spots cluster was a cluster that consistently appeared from 2014 to 2020. The Mubur, SW Munjan, E Munjan, S Lingai, and Mengkait hot spot clusters were found relatively new. The increase in the number of fishing boats detected in those new hot spot clusters is thought due to the increasing number of squid fishing gear in the area.

Keywords: fishing vessels; hot spot analysis; VIIRS boat detection

INTRODUCTION

The Anambas Islands is an archipelago district in the Riau Islands Province which is located in the Natuna Sea and bordered by Malaysia, Singapore, Vietnam, and Thailand. In addition to being in a very strategic location, the Anambas Islands also have high fisheries potential and located in Fishery Management Area (FMA) 711. According to the Decree of the Minister of Marine Affairs and Fisheries Number 50 of 2017 concerning Potential Estimation, Allowed Catch Amount, and Utilization Level of Fish Resources in the Fisheries Management Area of the Republic of Indonesia, the FMA 711 has a total fishery potential of 767,126 tons.

Fishery potential has to be supported by good fisheries management. Policies applied to fisheries management activities require sufficient data, one of which is data related to fishing areas. This information on fishing areas can be used as an information base in the fisheries management, predicting potential fishing areas, estimating fish distribution and stock, monitoring fishery activities related to spatial and zoning suitability, and also law enforcement regarding fisheries activities. According to Suniada (2018), MCS (monitoring, controlling, and surveillance) operations as an effort to fight IUU (illegal, unreported, and unregulated) fishing activities can be done by monitoring the distribution of the vessels. In addition, monitoring fishing vessels can also be effective for monitoring fishery activities in conservation areas, especially in the National Marine Protected Area (MPA) of the Anambas Islands and the Surrounding Sea Marine Tourism Park (MTP).

Utilization of remote sensing technology to extract information related to the distribution of fishing vessels can be performed in various ways, one of them by using the VIIRS (Visible Infrared Imaging Radiometer Suite) day/night band (DNB) images. The VIIRS DNB imageries collected by the Suomi National Polar Partnership (SNPP) satellite that launched in 2011. This satellite recorded a coverage area of 3,000 km with an altitude of 2,600 km. The VIIRS DNB products has significant capabilities in the context of detecting

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anthropogenic light sources, including the movement of ships (Miller, *et al.*, 2013). Although this data cannot inform the owner of every detected vessel, this VIIRS data helps improve fisheries management and fighting IUU fishing (Elvidge, *et al.*, 2015). Indonesia has also implemented a Vessel Monitoring System (VMS) to monitor fishing activities in its territory, but because the VMS only applied for fishing vessels over 30 GT, which only cover about 10% of fishing vessels throughout Indonesia, VIIRS data is considered more representative in mapping fishing areas (Elvidge, *et al.*, 2018; Hsu, *et al.*, 2019).

The application of VIIRS data for research related to fishing areas has been carried out quite a lot in Indonesia, such as to map light fishing areas in Pandeglang waters (Susanto, 2015); validate information on potential fishing zones in the Java Sea (Hamzah, *et al.*, 2015); and map fishing operations of lifting nets and ring trawlers in the Java Sea based on the moon phase (Lumban-Gaol, *et al.*, 2019; Lumban-Gaol, *et al.* 2020). Similar research has also been applied in several countries, such as estimating the fishing effort of *Ommastrephes bartramii*, *Todarodes pacificus*, and *Cololabis saira* in Japan (Liu, *et al.*, 2015); tracking the Arctic Ship for fisheries management (Straka, et al., 2015); estimating the IUU fishing catch amounts in the northwestern Pacific adjacent to the Japanese EEZ (Oozeki, et al., 2017); knowing the spatiotemporal pattern of potential fishing areas for trawlers in the East China Sea (Luo, et al., 2018); detecting fishing vessels in the Yellow Sea (Chen, *et al.*, 2019); comparing fishing fleet detection with AIS and VIIRS in FA Major Fishing Area 41 (Ruiz, *et al.*, 2020); and mapping the horizontal distribution of light fishing vessels in the East China Sea (Saito, et al., 2020).

This study aims to (1) determine the distribution of fishing vessels detected through the VIIRS boat detection images, and (2) determine the distribution of fishing vessels' hot spots. The study area studied covers the sea waters of the Anambas Archipelago in the period of 2014 to 2020. Through this data on the distribution of fishing vessel hot spots, it will be possible to identify fishing areas with the highest frequency. This information will be beneficial for planning fisheries management in the Anambas Islands.

MATERIALS AND METHODS

Materials

This research uses VIIRS Boat Detection (VBD) images. VBD imagery is a derivative product of the SNPP (Suomi National Polar Partnership) satellite which uses a Visible Infrared Imaging Radiometer Suite (VIIRS) sensor. The SNPP satellite is a satellite operated by NASA and NOAA that records low light data (light imaging data) in the visible light spectrum. Since 2014, the Earth Observation Group (EOG) has performed an algorithm to detect boat locations based on light detection in VIIRS imagery to produce VBD products. VBD is available to the public on the https://eogdata.mines.edu/vbd/ page. In this study, annual Indonesia VBD imageries from 2014 – 2020 are used. Coastline spatial data obtained from the Geospatial Information Agency of Indonesia to determine the boundaries of the study area used in this study.

Methods

The method used in this study consisted of two main stages. First, the analysis unit of Anambas Islands sea waters extracted from the coastline data by performing *buffer* analysis. Buffer analysis operated using ArcGIS Pro 2.8.1 with a distance of 12 nautical miles from the coastline. Based on the buffer analysis, the Anambas Islands sea waters area in this study covers 1,758,751.5 ha. The map of the study area can be seen in Figure 1.

Second, a spatial statistical analysis was conducted to determine the hot spots of the fishing vessels' distribution. This analysis uses the Optimized Hot Spot Analysis method in the ArcGIS Pro 2.8.1 application that runs the Hot Spot Analysis (Getis-Ord Gi*) algorithm by calculating Getis-Ord Gi* statistics on each pixel of the boat detection image. This analysis has been carried out to several case studies, such as determining the trend of commercial fishing hot spots in Australia (Jalali, *et al.*, 2015). The formula for the statistical analysis of Getis-Ord Gi* (Ord & Getis, 1995) is as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \bar{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{\left[n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}}$$

where xj is the attribute value for feature j, wi,j is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \qquad S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2}$$

RESULTS AND DISCUSSION

Results

Distribution of Fishing Vessels in Anambas Islands 2014 - 2020

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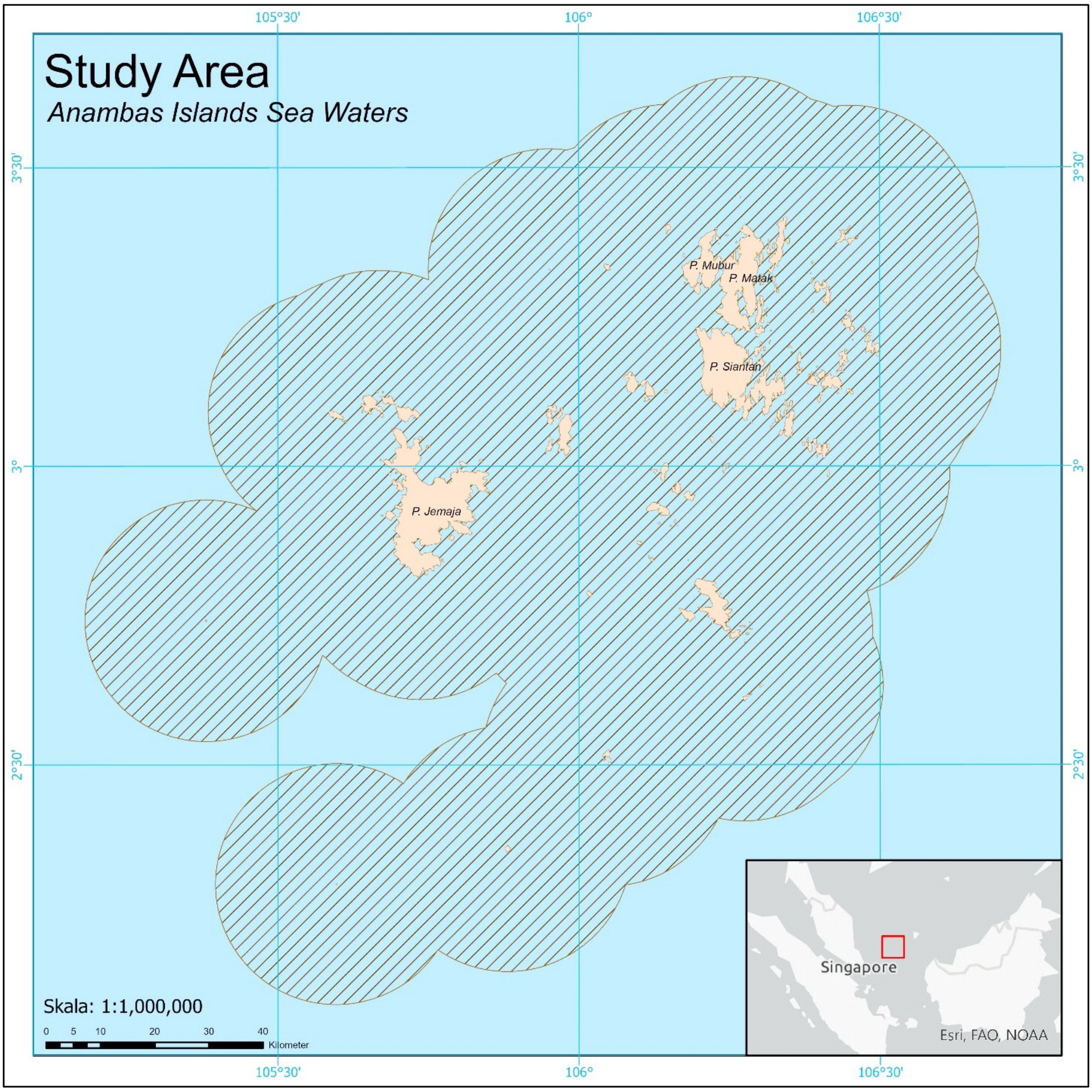

Figure 1. Study area

The sea waters of the Anambas Archipelago are part of the Fishery Management Area (FMA) 711 of the Republic of Indonesia. Based on the Decree of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 50 of 2017 concerning Potential Estimation, Permitted Catch Amount, and Level of Utilization of Fish Resources in the Republic of Indonesia Fishery Management Area In Indonesia, FMA 711 has a total fishery potential of 767,126 tons with the most commodities being small pelagic fish, large pelagic fish, and demersal fish. Based on their utilization status, the three main commodities of FMA 711 have been over-exploited for small pelagic fish, and fully-exploited for large pelagic fish and demersal fish. Fully-exploited means fishing effort can be maintained with close monitoring, and over-exploited means fishing effort must be reduced. According to Pregiwati, et al., (2017), there are 5 (five) types of fish that are the leading commodities in the Anambas Islands including grouper, squid, tuna, scomberomorini, and trevally.

The distribution of fishing vessels in the Anambas Islands is the distribution in the sea waters of the Anambas Islands with a distance of 12 nautical miles from the coastlines. According to Hsu, et al., (2019), generally, the types of fishing vessels in Indonesia detected by VBD are fishing vessels with lift nets and purse seiners. The extraction of the distribution of fishing vessels in the waters of the Anambas Islands was carried out from 2014 to 2020. Based on the analysis, there was a decrease in the number of fishing vessels until 2017, which then increased again in 2018. The 2014 was the year with the most fishing

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vessels in Anambas, as many as 8,332 fishing vessels detected. Meanwhile, the lowest number of detected vessels occurred in 2017, which was 5,542 fishing vessels. Compared to the number in 2014, there has been a decline in fishing vessels in 2017 by 33%. The number of fishing vessels detected each year is provided in Figure 2.

Spatially, the location of fishing vessels in the sea waters of the Anambas Islands is seen to be almost completely distributed throughout the study area. Figure 3 shows the distribution pattern of fishing vessels detected in the waters of the Anambas Islands and their temporal changes from 2014 to 2020. There is a significant increase in the number of detections of fishing vessels starting from 2017 at the south of Siantan Island (red box) and expanding to the southwest. This emergence was also followed by reduced detection of fishing vessels at several points, especially on the northeast side of the study area.

Hot Spots of Fishing Vessels in Anambas Islands 2014 - 2020

Data on fishing vessels detected in the Anambas Islands from 2014 – 2020 became the input for hot spot analysis. In executing the hot spot analysis, this study uses the Getis-Ord Gi* algorithm to identify statistically significant spatial clusters of the number of fishing vessel detections in a year in each pixel of the analysis area. This model will produce clusters of high numbers of vessels detection (hot spots) and low numbers of vessels detection (cold spots). However, this study will only focus on the detection of high numbers of vessels (hot spots). The modeling performed on the ArcGIS Pro application will produce a feature class with information on the z-score, p-value, and confidence level (Gi_Bin) value. The z-score and p-value will be used to reject the zero hypotheses (H0) or not in each pixel of the analysis area. This analysis is expected to obtain the distribution of pixels in the analysis area that has a clustered spatial pattern that is not generated from a random chance process. This study uses a confidence level of 99%. With this value, it is indicated that H0 is rejected when the probability of a pattern generated by random chance is very low or the probability of a random pattern is below one percent (< 1%). The distribution of hot spots from fishing vessels detected according to VBD data in the Anambas Islands sea waters from 2014 to 2020 can be seen in Figure 4.

Figure 4 shows several temporal changes in hot spots of fishing vessels in the Anambas Islands fishing area. From the analysis, there is one cluster that consistently becomes the hot spots, which is the Tokongnanas cluster (white circle). This cluster is the northernmost cluster from the sea waters of the Anambas Islands, and there is only one small island nearby, namely Tokongnanas Island. On the other hand, the analysis found the emergence of new hot spots clusters in 2019 and 2020 which are marked by the yellow and green circles in Figure 4. The new clusters in 2019 are the Mubur cluster and the SW Munjan cluster (yellow circles), while the new clusters in 2020 is the cluster of Mengkait, Lingai, and E Munjan (green circles). The emergence of these new clusters is thought to be due to the drastic increase in the number of *bagan* (lift net) fishermen in recent years. However, this assumption needs to be strengthened by primary data and further analysis.

Discussion

The distribution of hot spots fishing vessels in the Anambas Islands from 2014 to 2020 resulted in at least 16 hot spot clusters. These hot spots cluster

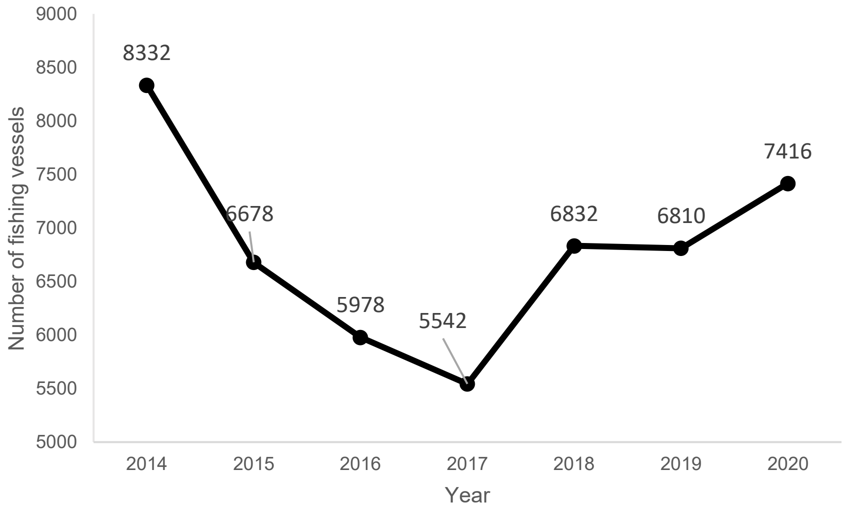

Figure 2. Number of fishing vessels detected from VBD data in Anambas Islands

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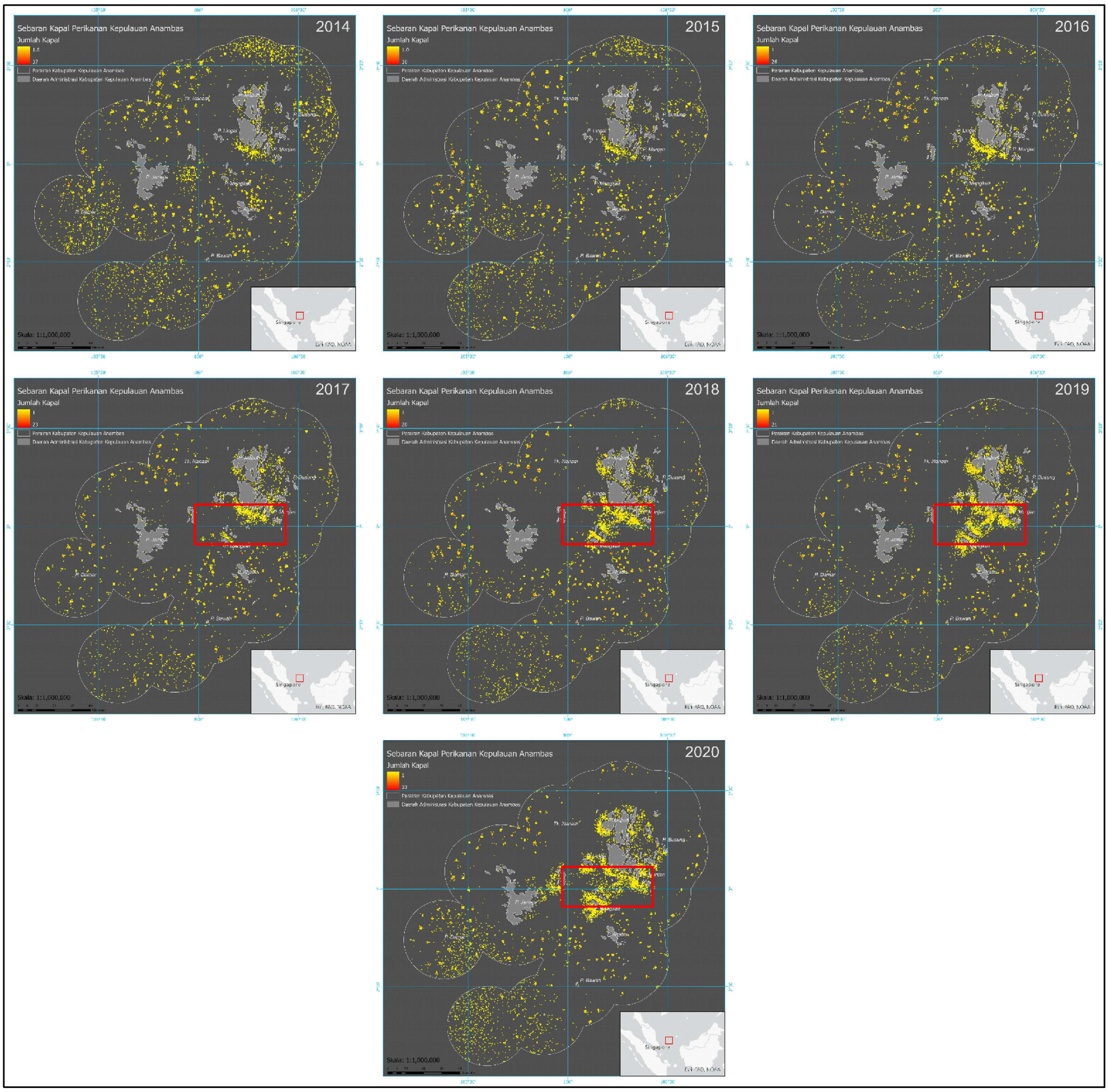

Figure 3. The distribution of fishing vessels in Anambas Islands 2014 – 2020

was identified to explain several hot spots phenomena. As previously explained, the Tokongnanas cluster is a cluster that has consistently been the hot spots in the Anambas Islands from 2014 to 2020.

In seven years of analysis, can be shown the trend of each hot spots cluster in the Anambas Islands. For example, in Table 1 it is known that the S Bawah cluster (16) has an overall downward trend, but in 2017 it increased dramatically. The decreasing of the fishing vessels numbers in the S Bawah cluster affects the hot spots results. In Figure 4 can be seen that the hot spots in the S Bawah cluster only occurred in 2014 and 2017 when the fishing vessels numbers are high. The distribution of 16 hot spot clusters on the map can be seen in Figure 5.

Based on the trend, the 16 hot spot clusters are further grouped into 3 (three) types of trends, which are those that tend to increase, tend to decrease, and tend to stagnate or fluctuate. The clusters with an increasing trend are the Mubur, S Lingai, Mengkait, SW Munjan, and E Munjan clusters. The clusters that have a decreasing trend are the Tokongnanas cluster, E Busung cluster, NE Airabu cluster, SW Airabu cluster, W Jemaja cluster, W Bawah cluster, and S Bawah cluster. Meanwhile, clusters with trends that tend to be stagnant or fluctuating are clusters of N Kiabu, SE Busung, S Jemaja, and S Damar.

Five clusters with an increasing trend turned out to be the hot spots clusters considered as the **new clusters**, as described in the discussion from the

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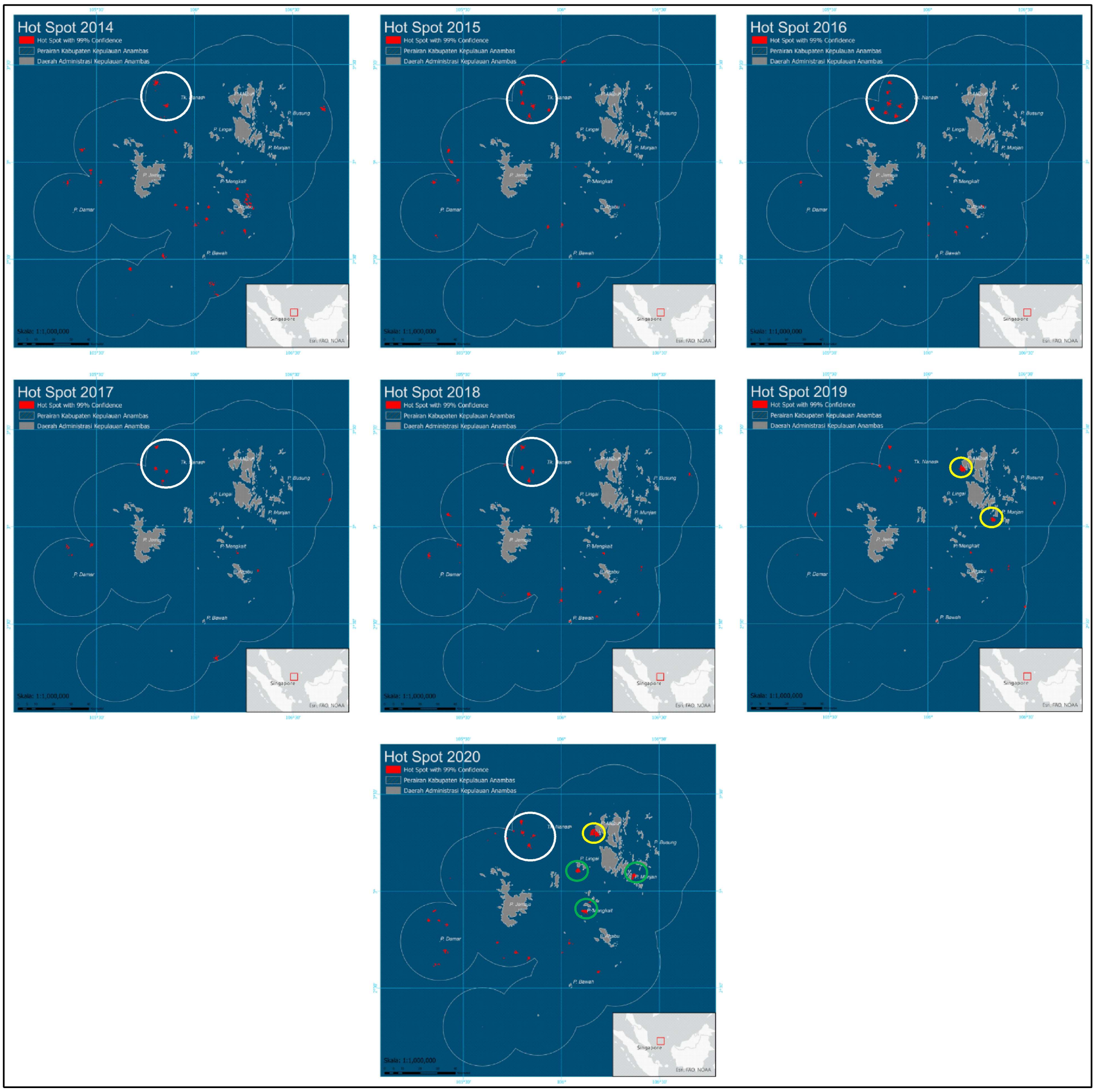

Figure 4. Hot spots of fishing vessels in Anambas Islands 2014 – 2020

previous section. Among the five clusters, the Mubur and SW Munjan (yellow circles) clusters were the first new clusters identified as hot spots in 2019. If we look at the trend in the number of fishing vessels detected (Figure 6), there was a significant increase in the number for each cluster, which are the Mubur and SW Munjan clusters occurred in 2018, and S Lingai, Mengkait, and E Munjan clusters in 2019.

The phenomenon of an increase in the number of fishing vessels detected in the emergence of new hot spot clusters is suspected to be the impact of the increasing number of lift net fishing boats (*bagan*) in Anambas, especially in the five clusters areas. The speculation made in this discussion cannot be confirmed in this study because the VBD data cannot distinguish the type of vessel or the owner of the detected fishing vessel. The assumptions raised in the results of this study need further research and studies the to confirm this. Meanwhile, Pregiwati*, et* al.*,* (2017) states that the *bagan* fishing gear in Anambas is normally used for squid fishing. Squid is considered to have a wider marketing area and more added value so the new emergence of *bagan* fishing is reasonable to have occurred in Anambas Islands. However, the rising number of *bagan* in the area of Anambas Islands as part of FMA 711 should be anticipated for sustainability reason. Suman (2016) suggest that the FMA 711 needs to decrease the number of *bagan* fishing for squids as much as 3,872 units based on the 2015 data.

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Table 1. Number of fishing vessels in each hot spots cluster

No.	Cluster	2014	2015	2016	2017	2018	2019	2020
1	Tk. Nanas	651	648	771	472	453	456	346
2	W Jemaja	390	452	306	263	288	166	207
3	S Jemaja	430	287	311	198	347	234	284
4	Mubur	0	3	7	25	108	211	176
5	S Lingai	0	0	7	10	28	53	68
6	E Busung	84	34	43	46	44	41	26
7	SE Busung	28	30	24	53	39	48	21
8	Mengkait	0	0	2	1	33	68	85
9	SW Munjan	7	20	28	38	75	91	48
10	E Munjan	5	8	4	23	27	65	63
11	S Damar	43	51	41	24	33	24	68
12	N Airabu	44	15	28	40	50	36	30
13	NE Airabu	288	163	136	95	106	88	32
14	SW Airabu	174	137	173	94	142	73	71
15	W Bawah	131	82	51	55	57	37	26
16	S Bawah	122	89	53	117	64	62	41
	(not hot spots)	5935	4659	3993	3988	4938	5057	5824
	Total	**8332**	**6678**	**5978**	**5542**	**6832**	**6810**	**7416**

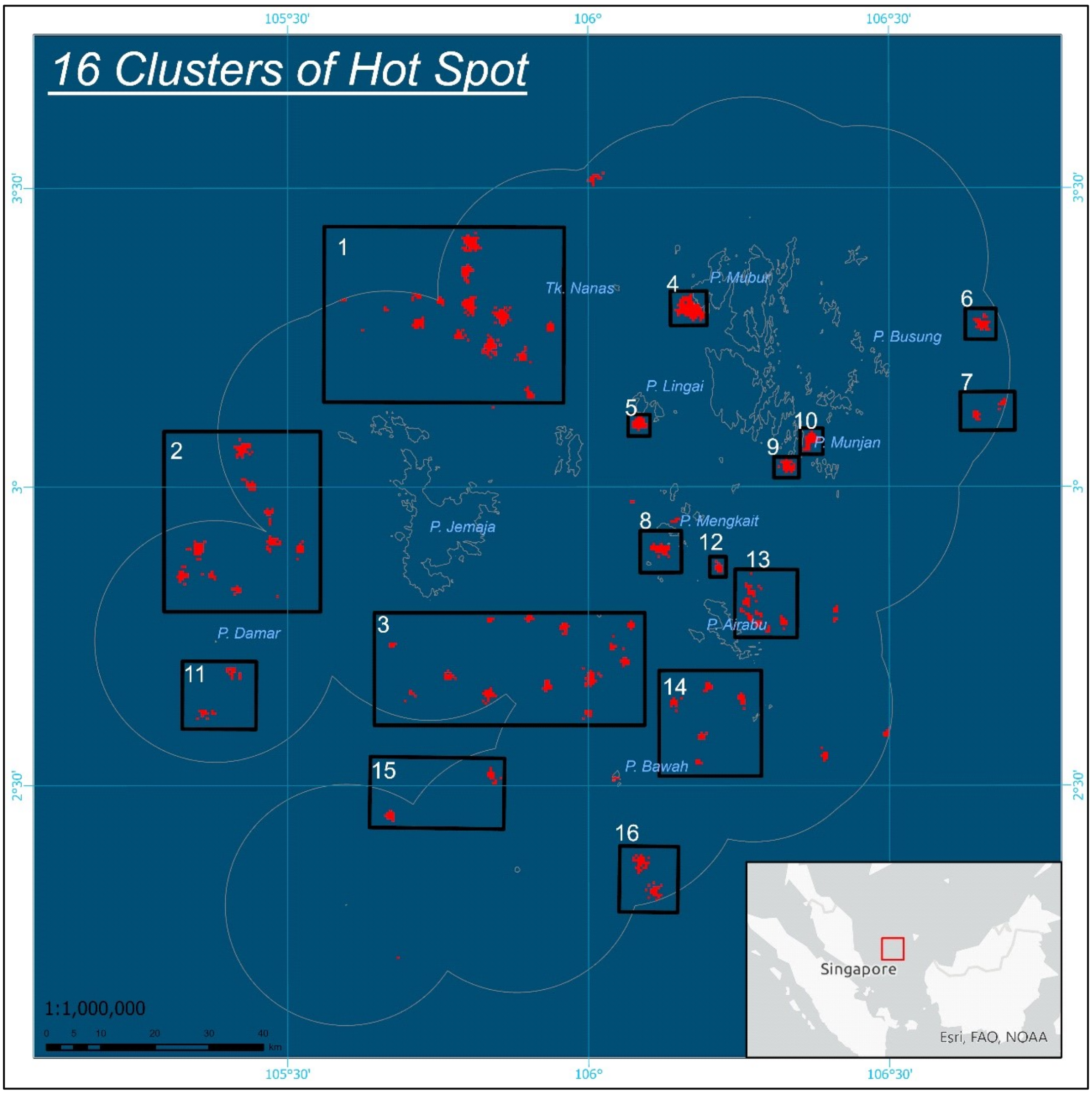

Figure 5. Sixteen clusters of hot spots

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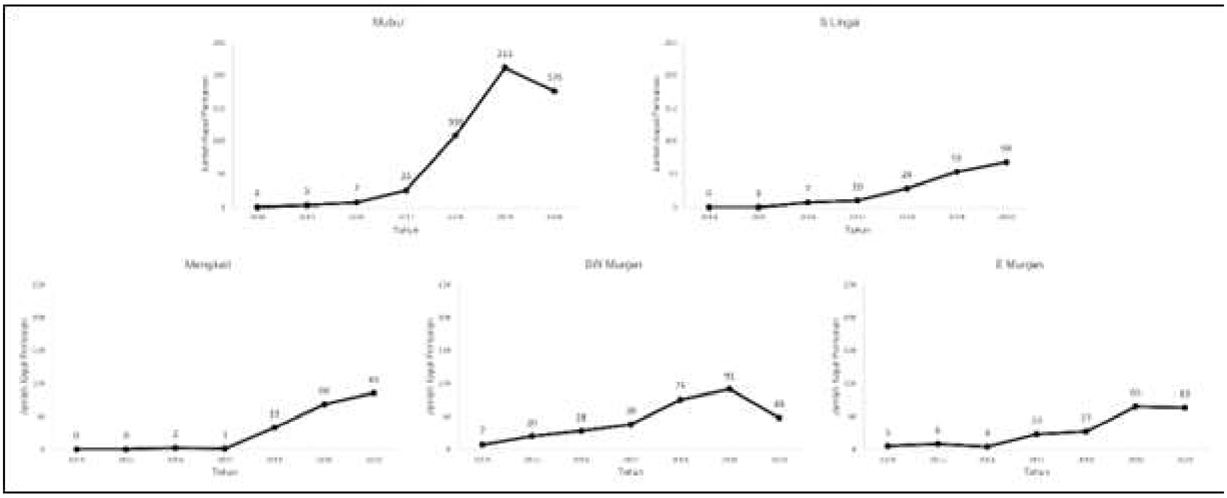

Figure 6. The numbers of fishing vessels in Mubur, S Lingai, Mengkait, SW Munjan, and E Munjan clusters

CONCLUSION

Based on VBD data in the Anambas Islands, the distribution of fishing vessels detected is almost completely distributed in the waters of the study area. Spatiotemporally, there was a change in the fishing vessels' location that was quite prominent starting in 2017, especially in the south of Siantan Island which then expanded to the southwest until 2020. Through hot spot analysis, it is possible to identify points of high-frequency fishing activity based on the location of the vessels derived from the VBD data in the Anambas Islands. There are at least 16 fishing vessel hot spot clusters identified in the sea waters of the Anambas Islands. Of the 16 clusters, the Tokongnanas hot spots cluster is a cluster that has consistently been the hot spot for fishing vessels in the Anambas Islands from 2014 to 2020. Also, there are 5 (five) hot spot clusters that are relatively new to have emerged in the last two years and have an increasing trend in the numbers of fishing vessels. Those clusters are the Mubur, SW Munjan, E Munjan, S Lingai, and Mengkait clusters. These emerging new clusters are thought to be due to the massive increase in the lift net fishing gear (*bagan*) use in the Anambas Islands in recent years. Further research is deemed necessary to confirm these conditions and to provide input regarding the prediction of growth in the use of these fishing gears. We also recommend for future study to observe the number of catchments in each cluster that has been found in this research.

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