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Mapping and Tracking Nighttime Fishing Activities within Japan EEZ using VIIRS Boat Detection

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Abstract

Nighttime fishing is one of the most efficient methods used in modern fisheries. About one quarter of Japanese annual sea surface fishery production is caught by fishing boats that use powerful light to attract fishes, based on their phototaxis. This study explored the potential application of the nighttime boat detection data, extracted from the Visible Infrared Imaging Radiometer Suite Day/Night Band (VIIRS DNB) images, for monitoring fishing activities. Nightly boat detection data from 2016 to 2020 were used to examine spatiotemporal patterns of nighttime fishing activities. Using Hierarchical Density-based spatial clustering of applications with noise (HDBSCAN), 127 clustered area were identified. The clustered area had different seasonality, reflecting differences in lighting sources and fishing methods. Within 127 clustered areas, 97 areas were identified as potential fishing area based on their seasonality and vessel density distribution inside. The results of spatiotemporal analysis showed good consistency with pelagic fish distribution in the East China Sea, Japan Sea and Pacific. Monitoring spatiotemporal pattern changes of fishing activities by firstly identifying high vessel density areas from VIIRS Boat Detection data is demonstrated to be an effective approach.

Keywords: Nighttime Fishing; Remote Sensing; VIIRS Boat Detection

1. Introduction

Japan fisheries and aquaculture production has decreased to one-third over the past 30 years. The main reason is thought to be decreasing in the amount of fish resources affected by changes of oceanographic environment, which leads to the establishment of sustainable fisheries resource management in recent years [1]. In addition, considering a fully-fledged declination on Japan population, the number of fishermen will continue to decline as the population ages. The continuous declining trend on fisheries and aquaculture production and the concept of resource sustainability leads to urgent requirements on fisheries resources management in Japan. This research addresses the limitations on technologies of monitoring fishing activities and focuses on the potential of nighttime images from VIIRS for vessel detection and aims to identify clustered fishing areas by VIIRS Boat Detection (VBD) data and conduct spatiotemporal analysis on classified fishing areas. Ultimately, this study intends to promote that nighttime light images can be effectively used to monitor nighttime fishing activities and contribute as the first step of building an integrated prediction system of fish resources in the future.

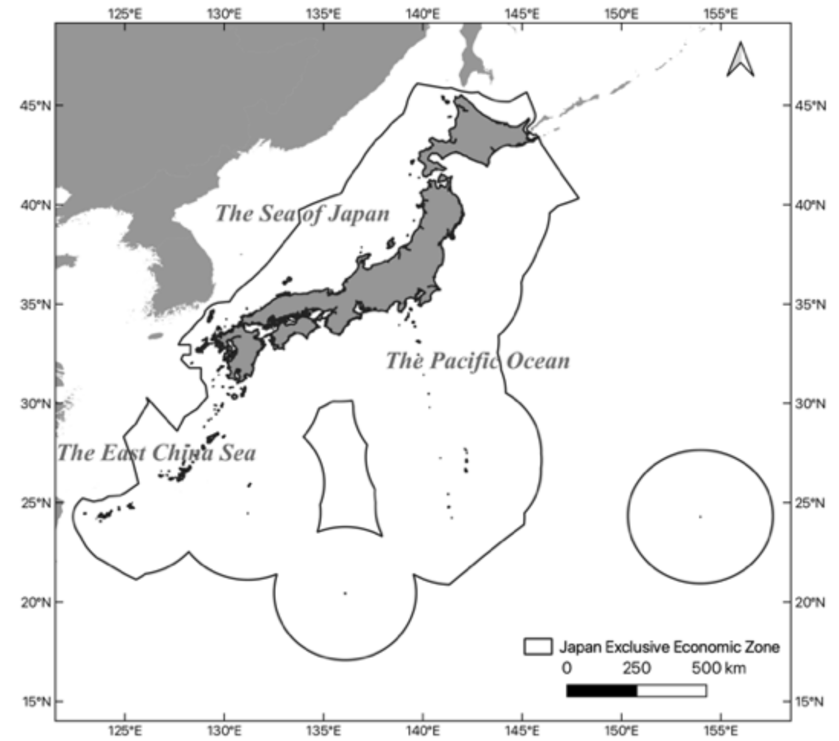

Figure 1: Study Area

2. Study area

Japan EEZ (Exclusive Economic Zone) is consisted of Japan Sea, and part of East China Sea and Pacific Ocean. The whole study area locates at the northwestern Pacific Ocean. In order to clarify and compare the actual status of fisheries by regions, the Japan Ministry of Agriculture, Forestry and Fisheries [2] has divided EEZ into nine sea areas based on their natural conditions such as oceanographic conditions, climate and fishery resources: Hokkaido North Pacific, Hokkaido North Japan Sea, North Pacific, Central Pacific, South Pacific, North Japan Sea, West Japan sea, East China Sea, and Seto Inland Sea.

Japan sea surface fisheries catch of 2020 is 3,156,500 tons, which is 75.6% of total fisheries and aquaculture production [2]. The production of nighttime fisheries related is 1,408,500 tons, which accounts for 44.6% of sea surface fisheries production. The main nighttime related fishing methods are purse seine nets, stick held lift nets and squid jigging. Excluding parts of large and medium-sized purse seine nets fleets which targeting tuna and skipjack tuna, all of these fisheries are operating within the Japan EEZ.

3. Methodology

Figure 2 shows the methodology of the research. VIIRS boat detection is carried out by the Visible Infrared Imaging Radiometer Suite (VIIRS) is one of the five instruments onboard the Suomi National Polar-orbiting (NPP) satellite platform that was launched on October 28, 2011. It observes and collects global satellite observations that span across the visible and infrared wavelengths for land, ocean, and atmosphere. VIIRS hosts a unique panchromatic Day/Night band (DNB), which is ultra-sensitive in low-light conditions that allow us to observe nighttime lights with better spatial and temporal resolutions compared to previously provided nighttime lights data by the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS).

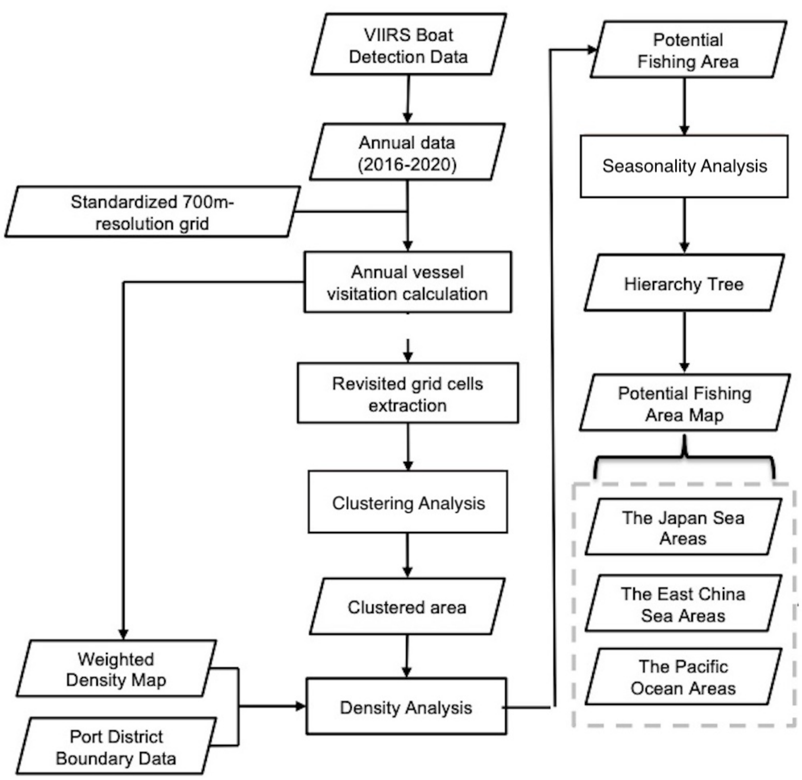

Figure 2: Methodology of the research

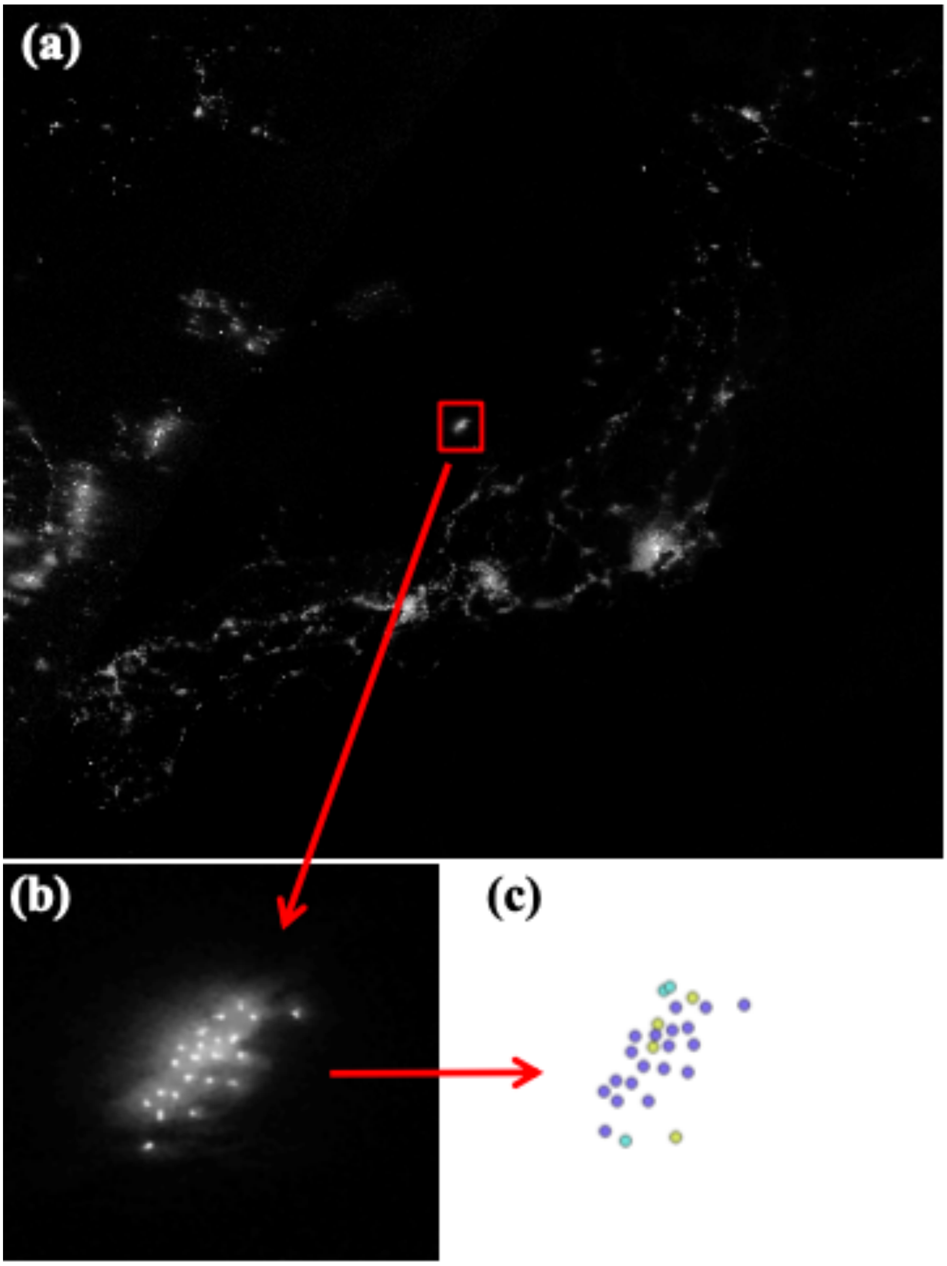

Figure 3: Examples of (a)VIIRS Nighttime light image; (b) Yamato Bank; (c) VIIRS Boat Detection

Figure 3 shows the examples of a VIIRS Nighttime light image, Yamato Bank and VIIRS boat detection results.

Earth Observation Group (EOG) has worked since 2014 on algorithms to report the locations of boat detected based on lights with low temporal latency [3]. The service started in Southeast Asia and has now been expanded to global. The VIIRS Boat Detection developed a set of algorithms for automatic detection of spike and characterization of the spike feature sharpness [4].

Clustering analysis on 5-years VIIRS Boat Detection data within Japan Exclusive Economic Zone was conducted. High vessels density areas were extracted using Hierarchical Density-Based Spatial Clustering of Applications with Noise (HDBSCAN) [4-6]. HDBSCAN can separate clusters of high density from ones of low density, which allows varying density clusters caused by different fisheries.

4. Results and Discussion

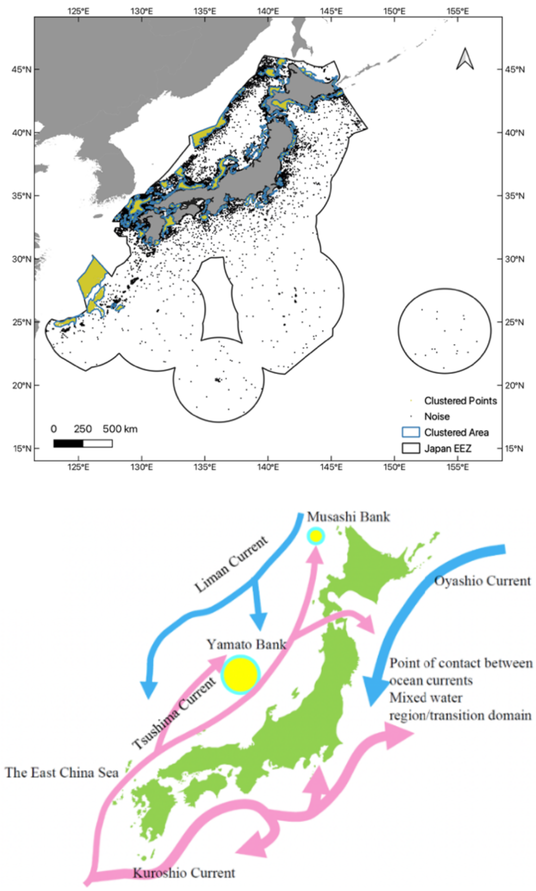

Figure 4: Results of Clustering Analysis and currents surrounding Japan (Vallerani et al., 2017)

Figure 4 shows the results of clustering analysis. Within 127 clustered areas, clustered areas that have no seasonality, or are extremely small, or overlapped with commercial ports and high-density marine transportation routes are removed. Finally, 97 areas were identified as potential fishing area based on their seasonality and vessel density distribution inside.

By applying hierarchical

clustering to average monthly visitation of each clustered areas, figure 5 shows average seasonal patterns of clustered areas. Clustered areas with similar seasonality have been divided into three groups based on the hierarchical tree. The peak vessels intensity month of each clustered area occurs more and more concentrated from left to right of the hierarchical tree.

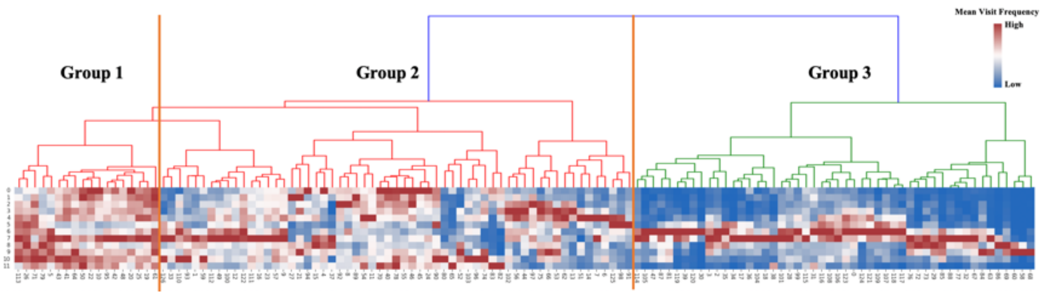

Figure 5: Average seasonal patterns

All nighttime fish species have characteristics of seasonal migration. Group 1 has high visitation frequency throughout the whole year. The seasonal patterns in group 2 are relatively complex, which may represent fishing areas with high catching density through several months, or mixture of fishing areas and non-fishing areas. Group 3 shows clear seasonality, which may indicate fishing areas for single fish species.

Considering difference on oceanographic structure and fisheries, spatiotemporal analysis was conducted for the Japan Sea, the East China Sea and the Pacific, respectively.

Figure 6 shows the distribution of clustered areas and monthly barycenter in the Japan Sea. There are 34 clustered areas in the Japan Seaside, including the South and West Japan Sea, and Hokkaido Japan Sea. The spatial pattern of monthly barycenter points indicates that there are more vessel activities in the North from July to Nov, while the South is predominant from December to June of next year.

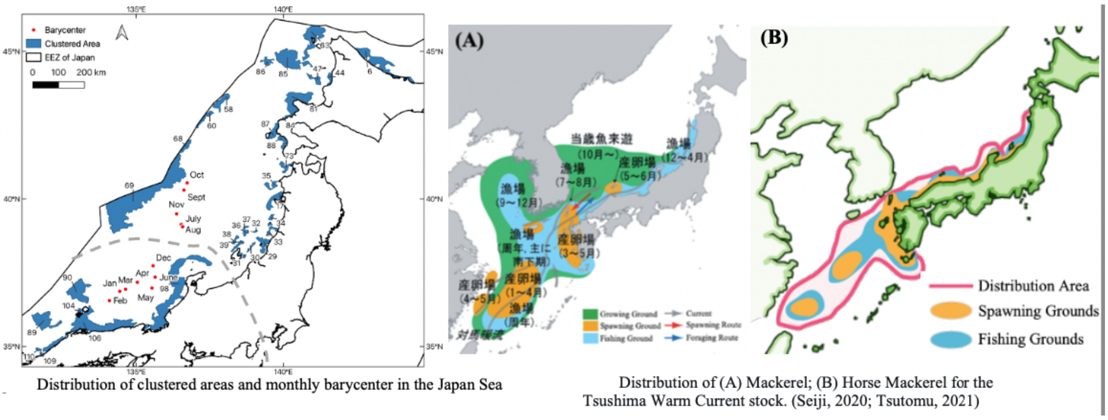

Figure 6: Distribution of clustered areas and monthly barycenter in the Japan Sea

Nighttime fisheries that operate in the Japan Sea are purse seine fishery and squid jigging fishery, targeting at the Tsushima Warm Current stock of sardine, mackerel, horse mackerel, and squid respectively. As of sea surface production of 2020, there is no production of purse seine fishery in the north of Japan Sea, purse seine fleets mainly conduct catches on the West Japan Sea, while operation of squid jigging happens across the whole area.

Figure 7 shows the distribution of clustered areas and monthly barycenter in the East China Sea. There are 28 clustered areas in the Pacific side, including the South, Central and North Pacific, and Hokkaido North Pacific. The clustered areas are mainly generated at two sea areas: the central of East China Sea and the Tsushima Strait, center at 34° N and 129°30” E. The clustered areas in the East China Sea are relatively larger than the other two areas, which means there are more concentrated vessels activities. It further demonstrates that these areas are highly possible to be fishing areas since no marine transportation route will be vast as these clustered areas

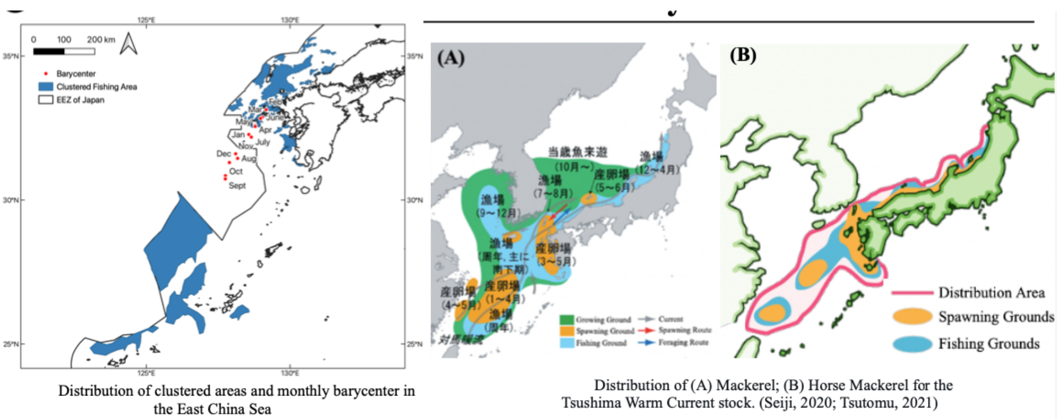

Figure 7: Distribution of clustered areas and monthly barycenter in the East China Sea

The distribution of monthly barycenter points reveals that vessel activities have focus on the Tsushima Strait in the first half of year, then move to the central East China Sea. Whole year vessels visitation can be observed both in the waters of Tsushima strait and central East China Sea from figure 7, while peak fishing season of the central East China Sea is the second half of year. The nighttime fisheries occur in this area are mainly purse seine fisheries. And since the East China Sea is the start point for both the Tsushima Warm Current stock and the Pacific stock, it has rich fish resources like sardine, mackerel and horse mackerel. Especially for horse mackerel, the East China Sea account for more than 50% of annual horse mackerel production in 2020.

Figure 8 shows the distribution of clustered areas and monthly barycenter in the Pacific. Although the Pacific side is the vastest sea area in the Japan EEZ, nighttime vessel activities have not been detected as much as other two sea areas. There are 35 clustered areas, scattering along the coastal area. Only two relatively broad areas, #49 and #66, which locate at the waters of east Hokkaido and the South Pacific respectively. All of three mainly nighttime fisheries will operate in the Pacific side because of its rich fish resources.

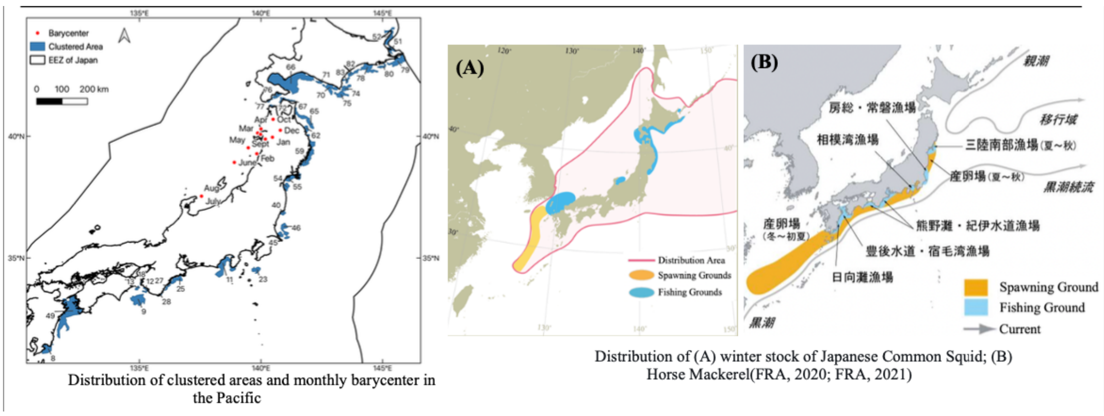

Figure 8: Distribution of clustered areas and monthly barycenter in the Pacific

However, Japanese government has prohibited the use of fishing light for purse seine fisheries at the North Pacific, which results in relatively small clustered area in the North Pacific than other sea areas. Except August and July, the monthly barycenter points aggregate at the north part, which indicates the north part have more vessels activities than the south part of the Pacific, which corresponds to the catch distribution in the Pacific. Figure 7 also implies that the Hokkaido North Pacific has the most vessel visitation through year. The clustered areas #49, 9, 11 have overlapped with fishing ground for the Pacific stock of horse mackerel.

And The clustered areas in the north part have covered fishing grounds of saury and the winter stock of Japanese common squid.

5. Conclusion

This research has revealed the potential and limitation of VIIRS Boat Detection data for monitoring fishing activities under large spatial scale. The spatial patterns of VBD data were analysis to extract high vessel density areas by clustering algorithm. And the underlying information of potential fishing areas were explored by combining four perspectives: 1) Distribution of VBD point within clustered areas; 2) Peak visitation seasons; 3) Calculation of barycenter and 4) Pelagic fishery resources review. The results of this research are in good agreement with pelagic fish distribution and ocean structures within Japan Exclusive Economic Zone. At current stage, monitoring spatiotemporal pattern changes of fishing activities by firstly identifying high vessel density areas from VIIRS Boat Detection data is demonstrated to be an effective approach.

References

[1.] Japan Fishery Agency (2018). Trends in domestic production of fisheries and aquaculture.

[2.] Ministry of Agriculture, Forestry and fisheries (2021), Production statistics of fisheries and aquaculture in 2020.

[3.] Elvidge, C.D., Baugh, K.E., Zhizhin, M.N., & Hsu, F. (2013). Why VIIRS data are superior to DMSP for mapping nighttime lights.

[4.] Elvidge, C.D., Baugh, K.E., Zhizhin, M.N., Hsu, F., & Ghosh, T. (2017). VIIRS night-time lights. International Journal of Remote Sensing, 38, 5860 - 5879.

[5.] Campello, R.J., Moulavi, D., & Sander, J. (2013). Density-Based Clustering Based on Hierarchical Density Estimates. PAKDD.

[6.] Campello, R.J., Moulavi, D., Zimek, A., & Sander, J. (2015). Hierarchical Density Estimates for Data Clustering, Visualization, and Outlier Detection. ACM Transactions on Knowledge Discovery from Data (TKDD), 10, 1 - 51.

[7.] Martí, M Vallerani, P Ojamaa, 2017, Research for PECH Committee – Fisheries in Japan, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.