RATING THE EFFECTIVENESS OF FISHERY CLOSURES USING VIIRS BOAT DETECTION DATA

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ABSTRACT: One of the primary methods used to reduce catch pressure on fishing grounds is to close them off, banning commercial fishing or particular vessel classes or gear types. Closures can range from ad hoc, to seasonal, to permanent. Agencies managing closures typically have very little information for rating the effectiveness of closures and examining the impact of changes in regulations or enforcement regimes. One source of information indicating the presence of fishing boats in near real time are the vessel detections from the NASA/NOAA Visible Infrared Imaging Radiometer Suite (VIIRS). The VIIRS low-light imaging day-night band (DNB) detects lighting from thousands of vessels worldwide, every night. Our team produces nightly global VIIRS boat detection (VBD) in near real time and has developed methods to rate the effectiveness of fishery closures. We examine case studies from the Philippines and China, with the calculation of closure compliance rates.

1. INTRODUCTION

Fishery closures are bans on fishing activity for defined spatial regions for specified temporal ranges. The purpose is to curtail fishing effort to accomplish specific management objectives, such as to reduce interference with fish breeding or to protect stocks of juvenile fish (Gell and Roberts, 2003). Fishery closures may be seasonal, permanent, or ad hoc. They may apply to a specific catch species or to an identified class of fishing gear. Many nations use fishery closures as part of their management of fishery resources. Rating compliance levels for fishery closures is challenging, in part due to limits on fishery agency patrol capabilities, inability to know the origin of landed catch, and the vast and remote expanse of many closures. In certain fisheries, compliance can be monitored with boat location data from onboard Automatic Identification System (AIS) or Vessel Monitoring Systems (VMS). Requirements for AIS and VMS generally covers only the larger boats, with smaller boats able to operate “under the radar”. Because there are large numbers of fishing boats that carry neither system, it is clear that other sources of fishing boat data would be required for rating the effectiveness of closures.

Since the 1970’s it has been known that low light imaging satellite sensors are able to detect fishing boats that use lights to attract catch (Croft, 1978). The original system exhibiting this capability was the U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). Several studies documented the OLS’ ability to detect lit fishing boats. Rodhouse et al. 2003 published a review of fishing grounds where the OLS detected fishing boats. The follow-on sensor with low light imaging capabilities is the NASA/NOAA Visible Infrared Imaging Radiometer Suite (VIIRS). The first VIIRS was launched in 2011 and the second in 2017. Three additional VIIRS instruments are planned, with data collection extending to 2035 or beyond. Compared to the OLS, the VIIRS day/night band (DNB) collects low light imaging data with substantial improvements in spatial resolution, detection limits, dynamic range and calibration (Elvidge et al., 2013). An automatic algorithm for vessel detection with nighttime VIIRS data was developed by the Earth Observation Group (EOG) and has been in operation since 2015 (Elvidge et al. 2015). Several test cases showing the calculation of fishery closure compliance levels with VIIRS boat detection data were published by Elvdge et al., 2018. The objective of this paper is to examine two more test cases.

2. Methods

2.1 Study Sites

In this paper we analyze VIIRS boat detections for two fishery closures. The first is a seasonal closure in Chinese waters offshore from Shanghai in the East China Sea from 26.5 north to 35 north. This is just part of the full set of seasonal fishery closures in Chinese waters. See Figure 1 for a location map of the area we analyze. The date ranges for this closure are drawn from announcments published by the Chinese Ministry of Agriculture and Rural Affair (MOA, 2018 and 2019). The area had closures extending back to 1998, however, in this study we focus on 2018 and 2019. The announcements states that all commercial fishing is banned in 2018 and 2019 from May 1 to August 1. Several gear types are permitted to resume fishing from August 2 to September 16, including shrimp trawlers, pot/trap/ spiky net, and lit purse seiners. Restrictions on commercial fishing ended on September 16.

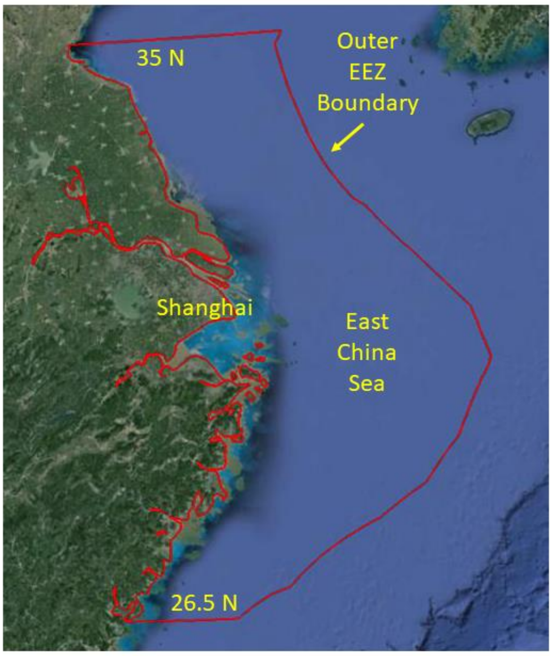

Figure 1. Image map showing the location of the seasonal fishery closure in the East China Sea.

The second study area are the “municipal waters” associated with the San Pascual LGU (local government unit), offshore from Burias Island in Masbate Province, Philippines. Here commercial fishing is banned year-long from shore out 15 km. This ban has been in effect since 1998 (BFAR, 2018). Table 1 provides a summary of the years and months where the closures were active.

Figure 2. Location map for the San Pascual municipal waters fishery closure.

Table 1
Description of the studied closures

Closure Location	Study Years	Start Date	End Date	Notes
East China Sea Seasonal Closure	2018 & 2019	May 1	August 1	Ban on commercial fishing starting at noon on May 1.
East China Sea Seasonal Closure	2018 & 2019	August 2	September 16	Ban lifted on shrimp trawlers, fish traps, spiky net, and lit purse seiners lifted at noon on August 1. Ban on other fishing gear types continues until noon on September 16.
San Pascual, Masbate, Philippine Municipal Waters	2012-2019	January 1	December 31	Ban on commercial fishing.

2.2 Data Extraction

VBD temporal profiles were extracted for the two study sites using EOG's VBD database. The extraction tallies the nightly vessel detection numbers for the strong, weak, blurry, and recurring detection types. The nightly data were then aggregated to monthly totals to reduce lunar cycle effects (Elvidge et al. 2018).

2.3 VIIRS Closure Index (VCI) Calculation

The VIIRS closure index (VCI) is calculated based on boat detection numbers during the closure period as compared with the numbers from a reference timeframe outside of the closure period (Elvidge et al., 2018). For the China closure the VCI was calculated from the daily average VBD from May 1 to August 1 versus a corresponding period beginning on August 2. For 2018 the reference period ran from August 2 to September 24 to form two complete lunar cycles. In 2019 the reference period for the East China Sea closure ran from August 2 to the end of August because the September 2019 data were not yet available in the database.   In this case, the VCI calculation is testing the compliance levels of the gear types that are permitted to return to the area starting August 2, specifically the lit purse seiners, which are known to be readily detected by VIIRS (Hsu et al., 2019).

For the San Pascual closure the VCI focuses on a change in the enforcement regime which resulted in an abrupt drop in VBD numbers in July 2016.   The reference is taken as the average number of boat detections for the same month from years prior to the change in enforcement, spanning April 2012 through June 2016.

The VCI is calculated as a percentags, with 100% indicating total compliance with the closure (zero boat detections). A VCI value of 0% indicates no change between the closure and reference periods. The VCI formula is shown in Equation 1. To ensure that the VCI has the range -100 to 100, the denominator value is the maximum of the boat detection numbers from either the closure period or the reference period. In cases where the number of detections during the closure period is less than the reference number, the VCI value will be positive, otherwise the VCI value will be negative. With this formulation, a VCI of 50% indicates that the boat detection numbers were reduced by half from the reference period. Conversely a VCI of -50% indicates that the closure month tallied 50% more boat detections than during the reference period. The analysis is repeated for each month and each year the closure was active, providing a rating of the efficacy of the closure over time.

$$VCI=100((VBD\_cl-VBD\_ref)/max(VBD\_ref,VBD\_cl)) \quad (1)$$

Where VBDcl denotes the boat detections for the closure period and VBDref is the boat detections for reference period.

3. Results

Figure 3 shows the nightly VBD detection tallies for the East China Sea closure for January 1, 2018 through August 31, 2019. Here the VCI is calculating the compliance levels for the gear types allowed to return to the area on August 1 of 2018 and 2019. Of these gear types, only the lit purse seine boats are known to be routinely detected by VIIRS. Hsu et al. 2019 calculated VBD detection rates for purse seiners in Indonesia as 59% while fishing. In contrast, only 6.6% of shrimp trawlers were detected while fishing. The temporal profile in Figure 3 shows the lunar cycle pattern described by Elvidge et al., 2018. The detection numbers drop during the May 1 to August 1 period in both years. Then return to normal levels after August 2. The VCI compliance level was calculated at 77% in 2018 and 75% in 2019.

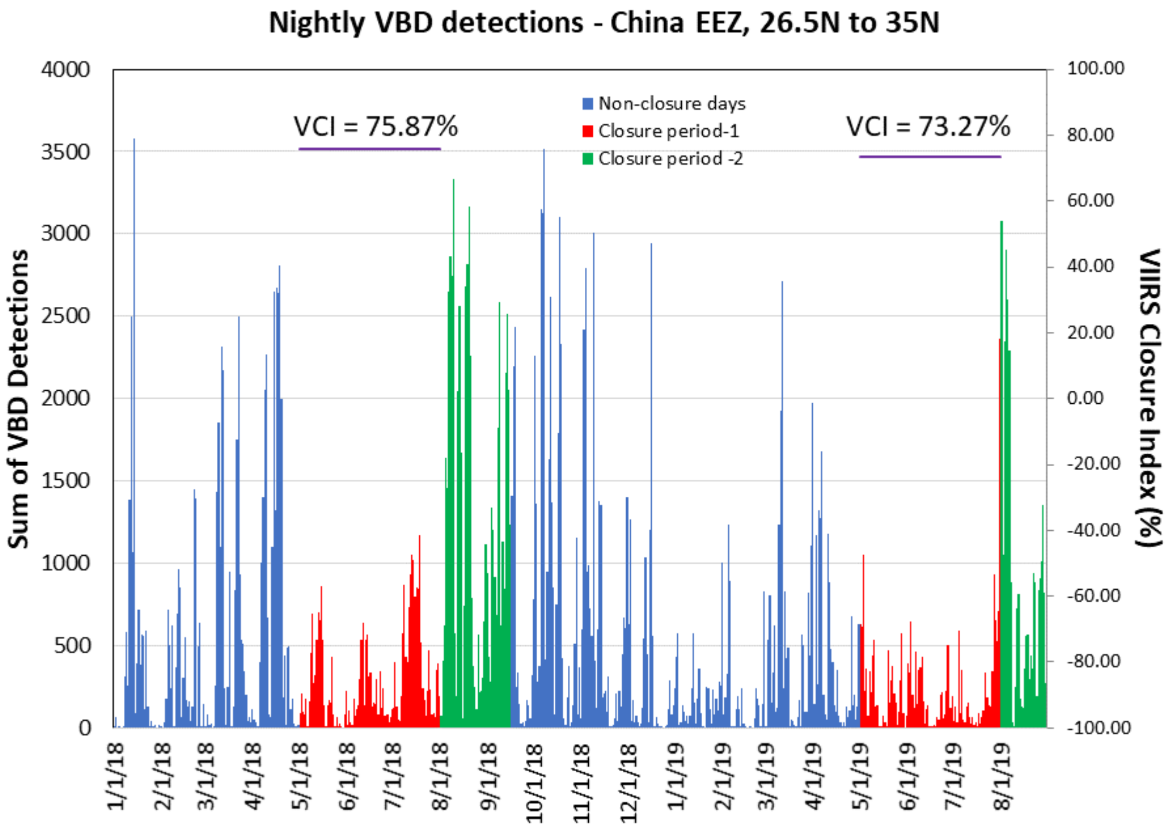

Figure 3. Nightly temporal profile of VBD tallies for the East China Sea fishery closure for 2018 and 2019. The horizontal lines indicate the VCI values.

Figure 3 shows the nightly VBD detection tallies for the East China Sea closure for Janurayr 1, 2018 through August 31, 2019. Here the VCI is calculating the compliance levels for the gear types allowed to return to the area on August 1 of 2018 and 2019. Of these gear types, only the lit purse seine boats are known to be routinely detected by VIIRS. The temporal profile shows the lunar cycle pattern described by Elvidge et al., 2017. The detection numbers drop during the May 1 to August 1 period in both years. Then return to normal levels from August 2 to September 15. The VCI compliance level was calculated at 76% in 2018 and 73% in 2019.

Figure 4 shows the monthly VBD tallies for the San Pascual municipal waters from April 2012 through July, 2019. Here commercial fishing has been banned since 1998. In the Philippines, purse seiners and ring net boats commonly work with specialized light boats, which aggregate fish from large volumes of water with large numbers of unshielded lights (superlights). The presence of the lightboats inside the 15 km boundary from shore is an indication of illegal commercial fiishing. VIIRS is unable to detect small local boats fishing legally since the lights they carry are low wattage and shielded. Figure 4 shows an abrupt drop in VBD numbers starting in July 2016. We interpret this as a change in the enforcement regime. For the next two years the compliance levels are quite high, in the range of 80 to 97%. The compliance levels drop stating in July 2018 and by February 2019 VBD detection numbers are in the range typical of the period prior to July 2016.

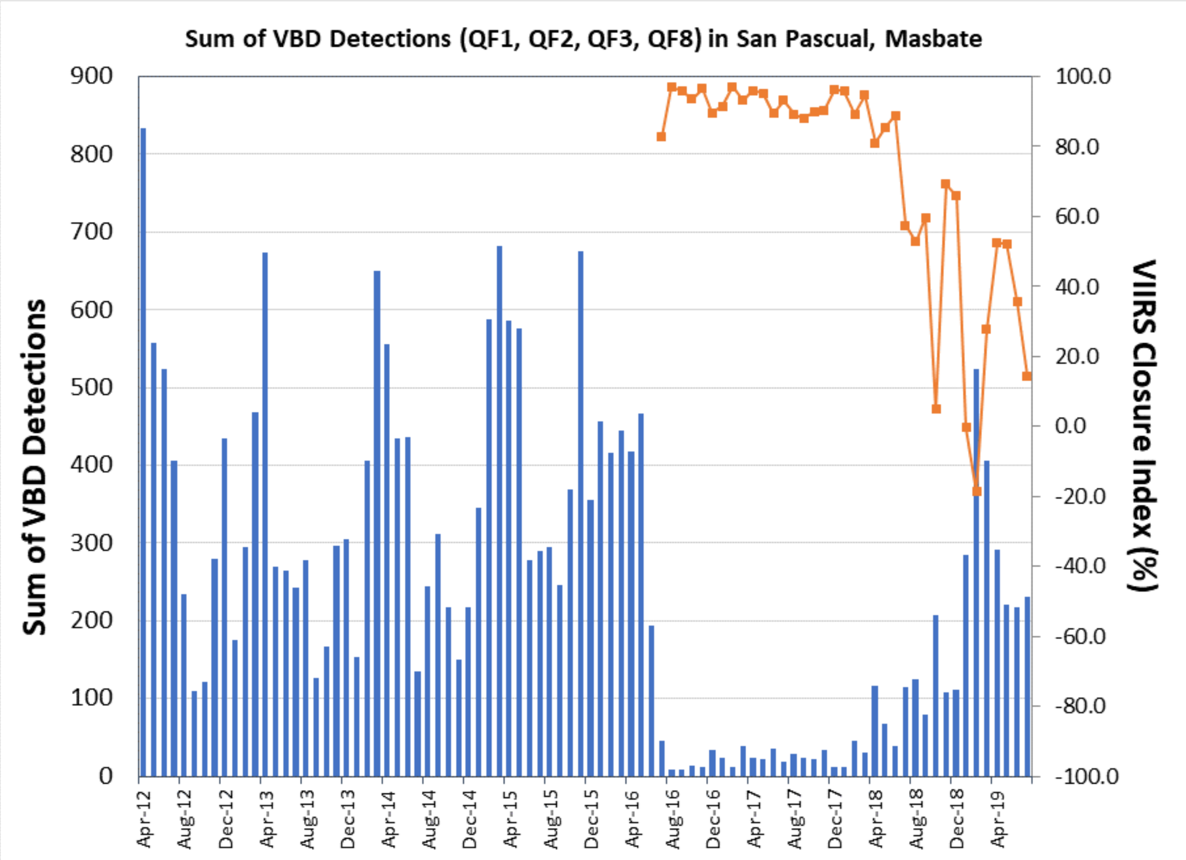

Figure 4. Monthly temporal profile of VBD tallies for the San Pascual LGU fishery closure for 2012 through July 2019. The orange line indicates the VCI values.

4. Conclusion

This paper demonstrates the use of VIIRS boat detections in rating compliance levels in fishery closures. Obviously, this data source is only useful in analyzing compliance in fishing grounds with vessels commonly using lights to attract catch or in the conduct of heavily lit nighttime operations. The analysis shows a high level of compliance (73-77%) in China's seasonal fishery closure in the East China Sea, where lit purse seiners are banned from May 1 through August 1. The compliance level for other banned gear types, such as shrimp trawlers and spiky net boats cannot be directly measured by VIIRS. In the second study site, San Pascual municipal waters in the Philippines, commercial fishing has been banned since 1998. Compliance with the commercial fishing ban is lax in some LGUs with rich fishing grounds and lax enforcement. While the San Pascual municipal waters only cover about 800 km2, the monthly VBD tallies were typically in the range of 100 to 800 until July 2016, when they dropped precipitously. The likely cause for this drop is a change in the enforcement that was highly effective. The enforcement actions were highly effective for two years and by 2019 the VBD numbers returned to their typical numbers from the period from 2012 to mid-2016.

The results from the two study areas confirm that fishing ground closure compliance levels can be effectively rated where there are numerous heavily lit fishing vessels. Since this style of fishing is widely used throughout Asia and many other areas around the world, VIIRS boat detections should be considered as a prime data source for rating and monitoring compliance levels in fishery closures.

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