ASSESSMENT OF FISH PRODUCTION VOLUME VIS-À-VIS NIGHT LIGHT DERIVED PRODUCTS IN THE PHILIPPINE MUNICIPAL WATERS

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ABSTRACT: Philippine municipal fisheries accounts for 85% of the fishing operators employment and 26.5% of the total fish production in 2014. Management and assessment of the fisheries resources can benefit on production and distribution models which require historical records in high temporal and spatial resolutions. Readily available fish production datasets either lack one or both of these requirements. Night light imagery, derived from the Visible Infrared Imaging Radiometer Suite Day-Night Band (VIIRS DNB), indicates areas that have artificial sources of emitted light in the visible region. Sources of artificial light such as those from fishing vessels are highly noticeable under clear sky conditions. Night light derived products were correlated with fish production volumes from the Philippine Statistics Authority (PSA). The clear sky product achieved the highest correlation but it was also observed that the relationship varied differently per region therefore two groups were considered. Two groups of regions were considered: group 1 comprising of Regions X, XI, XII, XIII and ARMM and group 2 consisting of Regions IV-B, VI, VII and Negros Island Region. The volume productions in these groups of regions increased with increasing clear sky product and were described by second-order polynomial equations with R^2 values of 0.7707 and 0.6597, respectively. These regional data showed that the clear sky product can locally serve as substitute to fish production volume. This fish production proxy also has adequate high spatial and temporal resolutions that is suitable for input to the models per group of region. A Generalized Additive Model (GAM) is constructed using Aqua Moderate-Resolution Imaging Spectroradiometer (MODIS) L3 monthly sea surface temperature and chlorophyll-a, and General Bathymetric Chart of the Oceans (GEBCO) bathymetry were considered as predictors and fish production proxy. The result of the model showed areas within the groups of regions that correspond to high production volume were identified.

1. INTRODUCTION

The fisheries sector accounts for 1.6% of the Philippines' Gross Domestic Products (GDP) based on the current prices in 2014. The Philippines is also acknowledged as the top 7th fish producing country in the world in 2013. This sector is divided into commercial fishing, municipal fishing, and aquaculture production. The municipal fishing activities from the coast to 15 km offshore constitutes 26.5% of the total volume of the country's 2014 fish volume production and employs 85% of the total fishing operators nationwide based on the 2002 census (BFAR, 2014). Proper resource assessment and management should therefore be implemented to support the sustainability of the fisheries sector. One way to contribute to this is to determine the fish distribution or production and limit the stressors in important fish habitats. Historical fish abundance data as input to spatial distribution models (SDM) coupled with remotely-sensed environmental predictors can result to distribution maps that can aid in fisheries management (Valavanis et al., 2008). Chlorophyll-a (chl-a) which is directly related to productivity, sea surface temperature (SST) and bathymetry are commonly used as explanatory variables. On the other hand, there is a lack of readily-available historical fish abundance or catch data in the Philippines, hence there is a need for high spatial and temporal substitute data. Studies show that fishing effort data are directly related to the number of fishing boats and fishers while the landings are highly correlated to environmental variables (Erzini, 2005). Fishing activities often involve the use of light attractor techniques. In fact, light from fishing vessels performs well in estimating the fishing effort for squid and saury species in Japan (Liu et al., 2015).

Panchromatic bands have been used to observe artificial light sources. The Visible Infrared Imaging Radiometer Suite Day-Night Band (VIIRS DNB), aboard the Suomi National Polar-orbiting Partnership satellite, is a panchromatic sensor capable of detecting light within the range of 500-900nm during night time. These night light imagery can detect urban and rural city lights, light reflecting off of clouds, lightning, gas flares, and lights from ships in the ocean.

Since the deployment of VIIRS, the ability to detect night lights with a daily temporal resolution has been improved. Recent studies by Elvidge (2015) and Liu (2015) have already shown the ability for VIIRS to detect fishing boats which use light attractors.

This study aims to derive a municipal fish production representative with sufficient temporal and spatial resolution and compare its distribution with environmental parameters such as chl-a, SST and bathymetry. Specifically, this study aims to determine the feasibility of using night light derived products as alternative to fish production volume, build a model to predict the fish production in specific areas and evaluate its performance.

2. METHODOLOGY

2.1 Development of night light products

An automated boat detection algorithm (BDA) developed by Elvidge (2015) was adapted and applied to daily DNB data over the Philippine region to produce quarterly night light composites. The algorithm uses two main inputs: the VIIRS DNB and VIIRS cloud mask product (CM). The lightning detection and sharpness index were not applied since they will only have minimal contribution to the quarterly composites.

The adapted algorithm contains several steps to produce quarterly night light composites. The DNB and CM were first gridded as 1 km. The boat detection algorithm was applied and daily night light and clear sky datasets were produced. The number of night light detections and clear sky observations per quarter were then summed to produce quarterly composites. A normalized night light quarterly composite was then produced by dividing the quarterly night light by the cloud-free observation composites. Quarterly products from 2012 to 2015 were produced for the entire Philippines.

The normalized night light product could be considered as a measure to indicate the probability of a pixel to contain a night light detection. However, under cloudy conditions, the algorithm would fail to detect any night light present. Under cloudy conditions, the normalized night light product may only contain a few number of cloud-free detections per pixel (e.g. 2 detections/quarter). The clear sky observations may be used to measure the confidence of the per pixel output of the night light product with a higher number of cloud-free observations. Low clear sky observations may produce relatively low confidence outputs.

2.2 Data collection of regional municipal fish production

Municipal fish production volume in metric tons was collected from the online database of the Philippine Statistics Authority (PSA) in http://countrystat.psa.gov.ph/. Quarterly production volume datasets from 2012 to 2015 per region were gathered. The datasets include the following species: Acetes, Anchovies, Big-eyed scad, Bigeye tuna, Blue crab, Caesio, Cavalla, Crevalle, Eastern little tuna, Fimbriated sardines, Flying fish, Frigate tuna, Goatfish, Grouper, Hairtail, Indian mackerel, Indian sardines, Indo-pacific mackerel, Muller, Parrot fish, Porgies, Round herring, Roundscad, Siganid, Skipjack, Slipmouth, Snapper, Spanish mackerel, Squid, Threadfin bream, Yellowfin tuna and others.

2.3 Modeling regional municipal fish production proxy

The most suitable night light product that can serve as fish production proxy was determined by calculating the correlation coefficient. Monthly 4km Level-3 Moderate Resolution Imaging Spectroradiometer (MODIS)-Aqua chl-a and SST products were downloaded from http://oceandata.sci.gsfc.nasa.gov/ and converted to geoTIFF using IDL 8.3. Bathymetry data in 30-arcseconds spatial resolution from General Bathymetric Chart of the Oceans (GEBCO) was also gathered. The values of these environmental parameters were extracted per fish production proxy pixel and stored in a master list which is used to build a Generalized Additive Model (GAM) using ArcMap 10.2.2 and R 3.2.1. The fish production volume of the 4th quarter of 2015 was predicted to assess the model performance. Figure 1 shows the general flowchart of the methodology starting from night light product development to fish volume prediction.

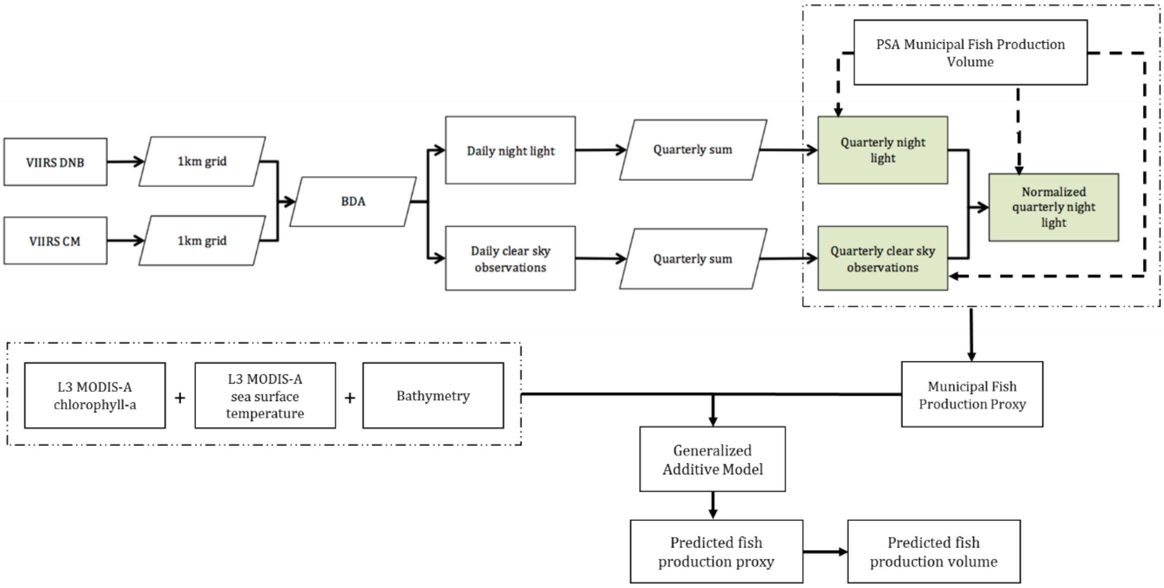

Figure 1. General flowchart of the methodology

3. RESULTS AND DISCUSSION

The three night light derived products were compared to the regional municipal fish production from the 3rd quarter of 2012 up to the 3rd quarter of 2015. It was observed that the relationship between the fish volume and night light frequency varies differently per region. Hence, two groups of regions alongside each other were considered. Group 1 consists of Regions X, XI, XII, XIII and Autonomous Region in Muslim Mindanao (ARMM) while group 2 is comprised of Regions IV-B, VI, VII and Negros Island Region.

Higher amounts of clear sky detections were obtained in the group 2 area compared to group 1. Figure 2 shows the total clear sky product from 2012 Q3 to 2015 Q4 and that the Western portion of the Philippines has a generally higher amount of clear sky data taken. This is because the center of the VIIRS DNB and CM products are located west of Region IV-B while the swath edges are located near the eastern side of the Philippines. Data in the center of VIIRS products have relatively high confidence compared to data near the swath edges.

Figure 2. Total clear sky observations taken from 2012 Q3 to 2015 Q4 where group 1 regions are enclosed in black lines and group 2 regions are highlighted in red

For both assigned groups, the clear sky product has the highest correlation with fish production as shown in Table 1 and Figure 3. This indicates that the fishing activities in the assigned group of regions are more dependent on weather and setting with less cloud cover than the frequency of artificial light which are assumed to be from fishing boats. Since small-scale fishing is the main source of the fish production volume in the municipal waters, it should also be noted that the discrepancy of the performance of the other night light products may be due to the unresolved light emitted from the smaller fishing boats.

Table 1. Equations and correlation coefficients for each product in region groups 1 and 2

Regions	Product		
	Cumulative Frequency	Normalized Frequency	Clear Sky
Group 1: Northern Mindanao, Davao Region, SOCCSKARGEN, CARAGA & ARMM	y = -3E-05x2 + 1.612x + 8021.2 R^2 = 0.6332	y = -0.0006x2 + 7.1091x + 5427.5 R^2 = 0.5505	y = -1E-07x2 + 0.0893x + 6148 R^2 = 0.7707
Group 2: MIMAROPA, Central Visayas, Western Visayas & Negros Island Region	y = 4087.1ln(x) - 7951.1 R^2 = 0.3486	y = -0.0002x2 + 4.5363x + 14185 R^2 = 0.2562	y = -6E-08x2 + 0.0849x + 10361 R^2 = 0.6597

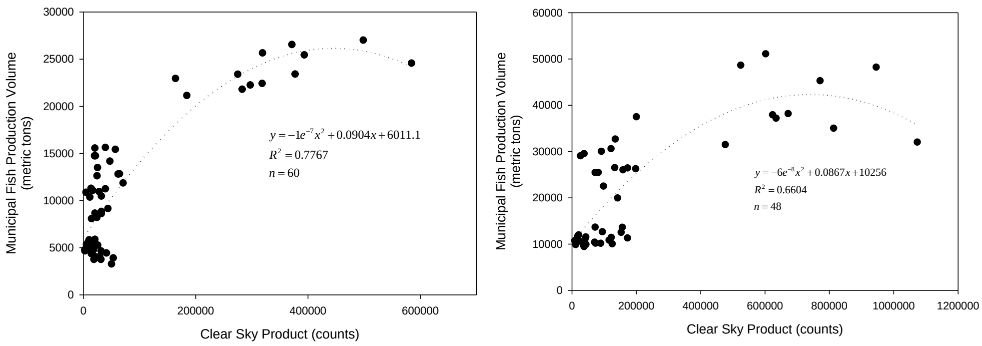

Figure 3. Municipal fish production volume compared with clear sky product for the regions in group 1 (left) and group 2 (right)

The clear sky product or production proxy then served as input to two models: one for each group of regions. The GAM is assumed in the form of Equation 1.

$$prediction\ proxy = (a * chl) + (b * SST) + (c * bathymetry) + (d * quarter) + e \quad \text{Eq. 1}$$

where a, b, c and d are the predictor coefficients and e is the error.

The response for the predictors are different for each model as shown in Figure 4. In the model for group 1, the production proxy increases with increasing chlorophyll-a, decreasing SST and decreasing bathymetry from -600m with peaks in the second quarter of the year. For the group 2 model, the production proxy decreases with increasing chlorophyll-a, increasing SST but with a peak around 30^{o}C and decreasing bathymetry from -400m in the first and second quarter of the year. However, though the ANOVA results suggests that all parameters are significant in describing the production proxy, the overall trendline in Figure 5 shows that the model did not perform very well in determining the absolute production presence values.

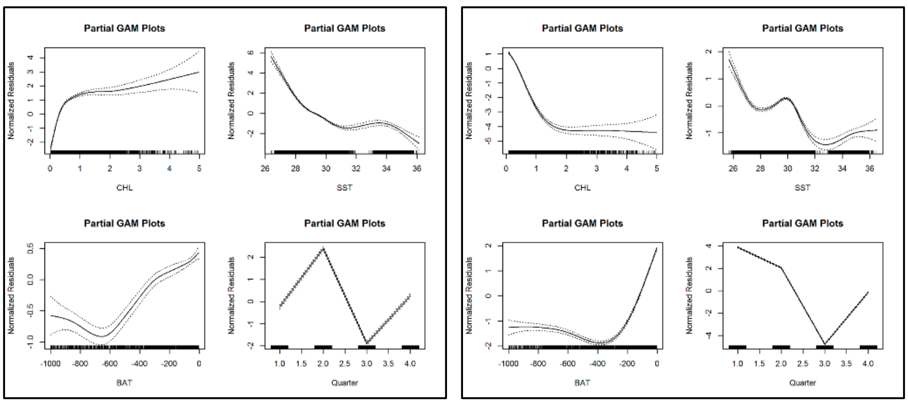

Figure 4. Partial GAM plots that summarizes the model for regions in group 1 (left) and group 2 (right)

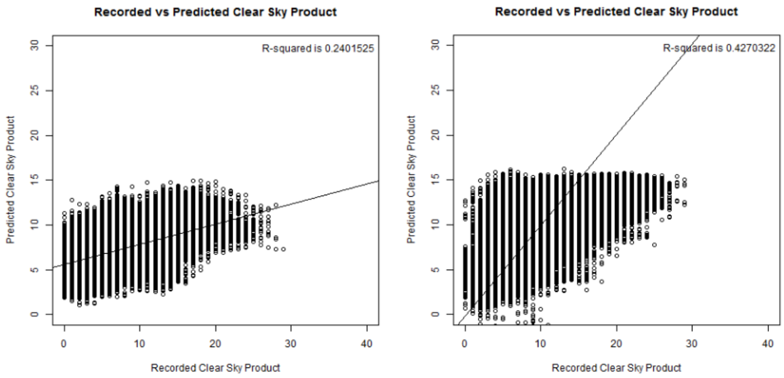

Figure 5. Recorded production proxy compared with predicted production proxy for the regions in group 1 (left) and group 2 (right)

Values for the 4th quarter of 2015 were used to further assess the performance of each model. Raster files of the environmental predictors were input to the models and the resulting production proxy were converted to fish production volume per region using the equations in Table 1.

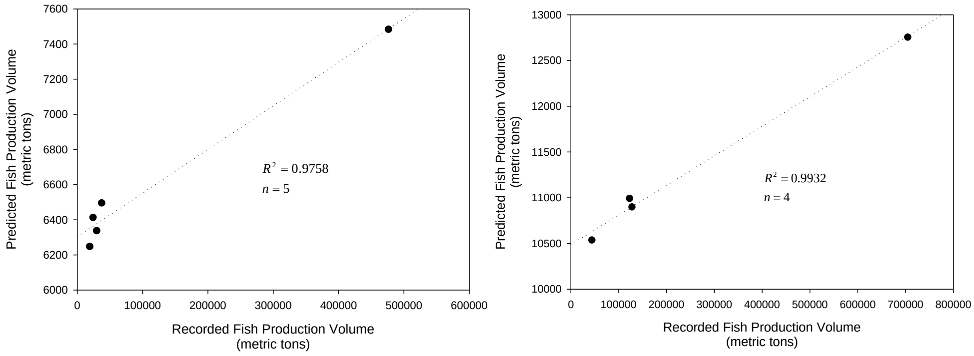

Figure 6. Recorded fish production volume compared with predicted fish production volume for the regions in group 1 (left) and group 2 (right) for the 4th quarter of 2015

Figure 6 shows that the predicted fish production of each region has an increasing trend with the true values but the absolute values are in different ranges. This implies that the predictors, chl-a, SST and bathymetry, which are commonly used in SDM's to describe fish abundance and distribution are insufficient to predict the absolute values of the production proxy. The production proxy map in Figure 7, still, demonstrates high fish production in the municipal waters of Region IV-B and ARMM which are regions with recorded high fish production volume.

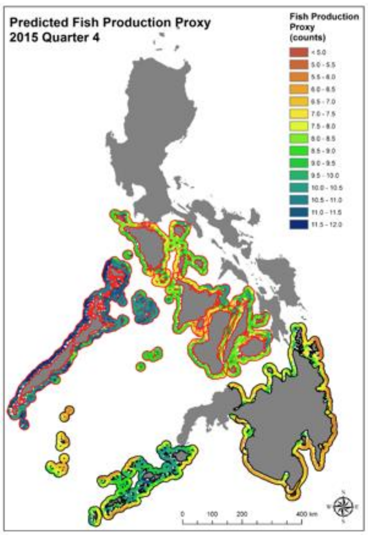

Figure 7. Predicted fish production proxy for 2015 Q4

4. CONCLUSION

It was found out that among the night light derived products, the clear sky product has the highest correlation with the municipal fish production volume dataset, implying that the production is more driven by weather-related conditions rather than the use of fishing light attractor devices. It is also possible that the night light frequency and normalized frequency does not account for the light in small fishing boats which are mainly in the municipal waters. Subsequently, the normal predictors that are commonly used to predict fish catch did not perform so well in predicting the absolute values of the production proxy though the latter is still as expected in terms of the trends. Hence, it is recommended to consider other environmental predictors and consider individual species production volume instead of the total. The model output, however, predicted high production in two well-known regions for fishing: region IV-B and ARMM.

5. ACKNOWLEDGEMENT

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