

An attempt of dissemination of potential fishing zones prediction map of Japanese common squid in the coastal water, southwestern Hokkaido, Japan

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Abstract:

Accurate prediction of potential fishing zones is regarded as one of the most immediate and effective approaches in operational fisheries. It helps fishermen reduce their cost on fuel and also decrease the uncertainty of their fish catches. To predict potential fishing zones of Japanese common squid, we derived fishing positions from the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS), combine with bathymetry and model-derived environmental factors from the 4D-VAR data assimilation system and fitted using habitat suitability index (HSI) model. Validations with an independent DMSP/OLS dataset showed better performance of the model in figuring out the squid aggregations than our previous model established with satellite-derived environmental data. Nighttime visible images during June and early July of 2013 derived from Day/Night band (DNB) of Visible Infrared Imaging Radiometer Suite (VIIRS) sensor with a better resolution and quality compared to DMSP/OLS, were also applied for validation and results showed differences of fitness between actual fishing activities and predictions in Japan Sea and Tsugaru Strait.

Keywords: Potential fishing zone, prediction map, Japanese common squid, nighttime visible data, 4D-VAR data, DMSP, VIIRS DNB.

1. Introduction

Japanese common squid (*Todarodes pacificus*) is one of the dominant target species in the coastal water of southwestern Hokkaido, Japan. According to the MAFF (Ministry of Agriculture, Forestry and Fisheries of Japan), landing records of this species by Japanese fisheries reached 166,400 tons in 2012 which almost accounted for 78% of Japan's total annual squid landings. The coastal waters of southwestern Hokkaido are the main fishing grounds for Japanese common squid and jigging fishing activities occur in this area from June until December. The powerful lights used by fishing vessels for attracting squid aggregations can be detected by using nighttime visible images to locate the daily presence and absence of squids [1].

Landing records of Japanese common squid fishery showed intense fluctuations during the past two periods of regime shifts in the Northwestern Pacific [2, 3, 4]. Due to the high sensitivity to ambient environment of Japanese common squid, catches vary along with the change of ocean conditions both spatially and temporally. Habitat suitability index (HSI) modeling is a robust tool to investigate various species-environment associations and has been often applied to predict potential fishing zones for fish species to facilitate fishing activities [5, 6].

Our previous studies employed satellite-derived environmental parameters to conduct predictions of Japanese common squid. We demonstrated that boosted regression tree (BRT) outperformed generalized additive model (GAM) and generalized linear model (GLM) on predicting potential fishing zones. Previous predictions also showed good performance in reflecting the actual fishing positions. Nevertheless, predictions using satellite-derived data sometimes had to suffer from the low area coverage due to adverse weather conditions, and hence posed difficulties in providing daily prediction maps to local fishermen. Model-derived oceanographic data from 4D-VAR data assimilation system have been proven appropriate in representing actual oceanic conditions in our study area [7]. Therefore, in the present study we implemented the predictions using 4D-VAR dataset and compared the performance with the previous derived results from satellite-derived environment data.

The better spatial resolution of VIIRS/DNB allows more detailed information on the fishing vessel positions than DMSP/OLS nighttime visible data [8,9]. The overpass time of NPP (around 01:30 local time) is more advantageous for light detection than DMSP (around 19:30 local time), this superiority is very notable during the summer season. The VIIRS/DNB highly improves fishing vessels detection compared to DMSP/OLS. In this study, we obtained a short period of VIIRS/DNB data to validate our predictions. The application of prediction maps during the actual fishing activity could have significant contribution to the Japanese common squid fishery development and therefore constituted one of the main starting points of our study.

2. Methods

2.1. Study area

Here we focus on the coastal areas of southwestern Hokkaido, Japan, which ranges approximately between 40.7°N – 42.7°N and 139°E – 142.7°E. Since current direction and velocity are included in the model and current features might be very different according to locations, the study area is divided into three sub regions: Japan Sea region, Tsugaru Strait region and Pacific region (Figure 1).

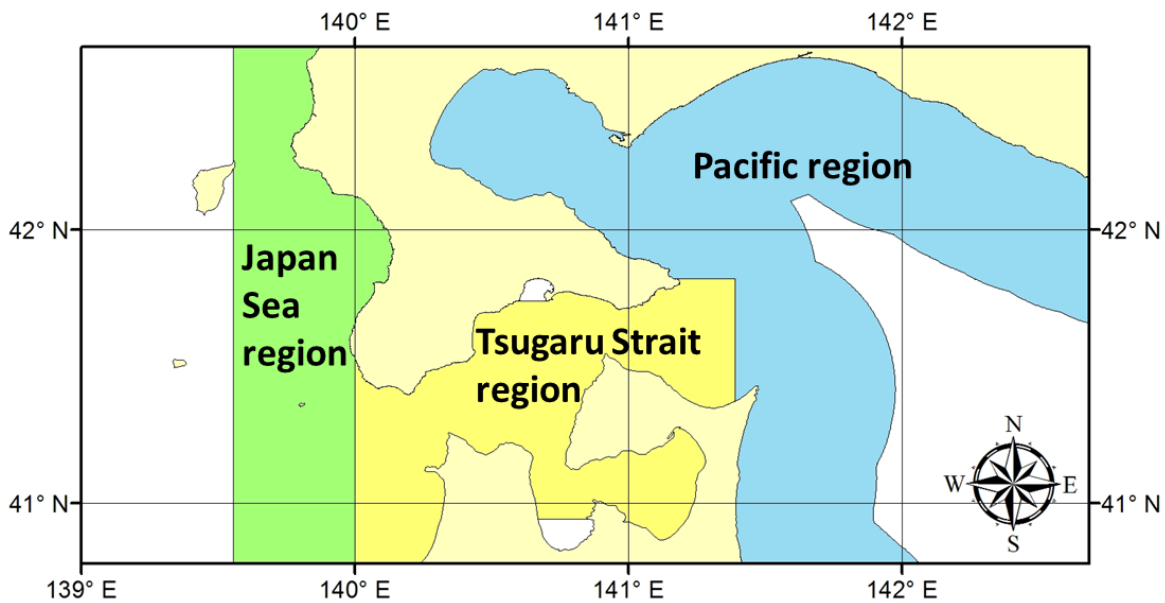


Figure 1. Divisions of the study area.

2.2. Data

The original 4D-VAR data consisted of twelve components recorded by single precision (Table 1). Eddy Kinetic Energy (EKE) at every depth was calculated based on the value of geostrophic velocity (u , v). We extracted some relevant parameters of a series of depth from 4D-VAR dataset and calculated the correlation coefficient of every extracted parameter at different depth bins at each fishing position obtained from the DMSP/OLS nighttime visible data from 2008 to 2010. The selection of 4D-VAR environmental parameters for modeling was based on comparisons of the correlation coefficients. Bathymetry data (JODC-Expert Grid data for Geographic-500m) were obtained from the archive of Japan Oceanographic Data Center (http://www.jodc.go.jp/data_set/jodc/jegg_intro.html).

Table 1. Details of original 4D-VAR dataset for our study area

Product name	Number of layers	Unit
<i>u</i>: Eastward velocity	78	cm/s
<i>v</i>: Northward velocity	78	cm/s
<i>w</i>: Vertical (upward) velocity	78	cm/s
Temperature	78	Celsius degree
Practical salinity	78	PSU
Seawater density	78	g/cm ³
Sea water level (height or elevation)	1	Cm
Barotropic eastward velocity	1	cm/s
Barotropic northward velocity	1	cm/s
TKE (turbulent kinetic energy)	78	erg/cm ³
MLD (mixed layer depth)	1	Cm
Vertical mixing coefficient	78	cm ² /s

The compiled dataset contained the daily presence/absence information of fishing vessels (derived from DMSP/OLS nighttime visible images) and the corresponding environmental factors. Seventy percent of the data were randomly extracted and used for model building and the remaining 30% were used for evaluating the performance of predictions. VIIRS/DNB data between June and early July of 2013 were used for model validations.

2.3. Model fitting and evaluation

We set up BRT to describe the relationship between squid occurrence and habitat variables. The BRT combines the strengths from two statistical techniques: regression trees and boosting. The model relate response to predictors by binary splits, so there is no limitations on shape and type of variables, the boosting helps optimizing the model accuracy through combine numbers of weak simple models into a reliable model. Three two-way interaction BRT models with 0.01 learning rate and 0.7 bag fraction were fitted for three different regions.

Performance of predictions was assessed on the basis of two statistical criterions: AUC (area under the receiver operation curve) and point-biserial correlation, which were calculated based on the data prepared for evaluation.

2.4. Validation using the VIIRS/DNB data

Thresholds were set to extract the fishing vessel locations from the VIIRS/DNB nighttime visible images. We overlapped those extracted fishing locations with daily prediction maps to extract the corresponding prediction value. Due to the low coverage of the occurrence of fishing vessels in the study area, prediction values were very low. We defined 0.1 as the critical prediction value of presence. The ratio of number of fishing located at predicted presence area to total numbers of actual fishing presence was calculated.

2.5. Practical application of the prediction model

Four-day prediction maps were sent to fisheries associations and fishermen at 9:30 am on a daily basis via Email and Fax. Some information of ocean environment derived from the 4D-VAR data assimilation system were also delivered to them. The prediction maps can be accessed through the website as well (<http://innova01.fish.hokudai.ac.jp/marinegis>).

3. Results

After comparing the correlation coefficient and considering behavior of the Japanese common squid, we decided to use bathymetry and the listed 4D-VAR parameters in Table 2 to fit the BRT model. The vertical velocity (w) was not included into the final modeling due to its very low correlation coefficient in every depth layer. For the area where water depth is lower than the depth with the highest correlation (50m/100m), we applied the parameters in 20m replacing the 50m and 100m to fit another model. This was then used for predicting shallow areas.

Table 2. Selected 4D-VAR factors for model building

Factors	Japan Sea	Tsugaru	Pacific
u	50m	50m	50m
v	50m	50m	2m
Temperature	50m	50m	100m
Salinity	50m	20m	50m
EKE	50m	50m	50m

Both AUC and correlation coefficients of 4DVAR-based BRT model were higher than our satellite-based BRT model (Table 3), indicating a large improvement of prediction performance with 4D-VAR dataset relative to the previous models. This result is also an evidence for the good consistency of 4D-VAR in reflecting the oceanographic features in this study area.

Table 3. Statistical criteria of model performance

Model	AUC	Correlation
4DVAR-based	0.86	0.29
Satellite-based	0.82	0.23

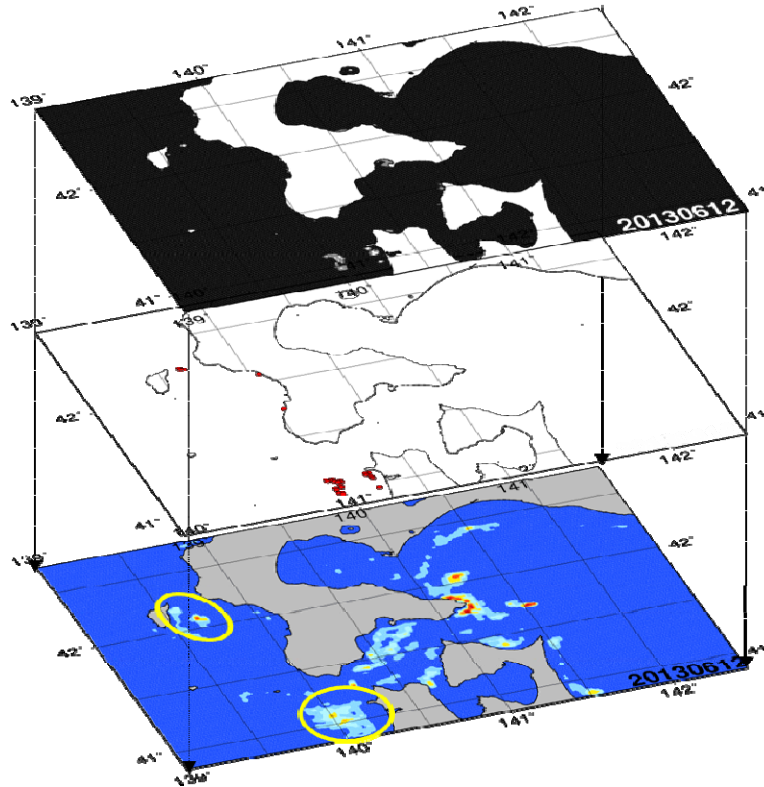
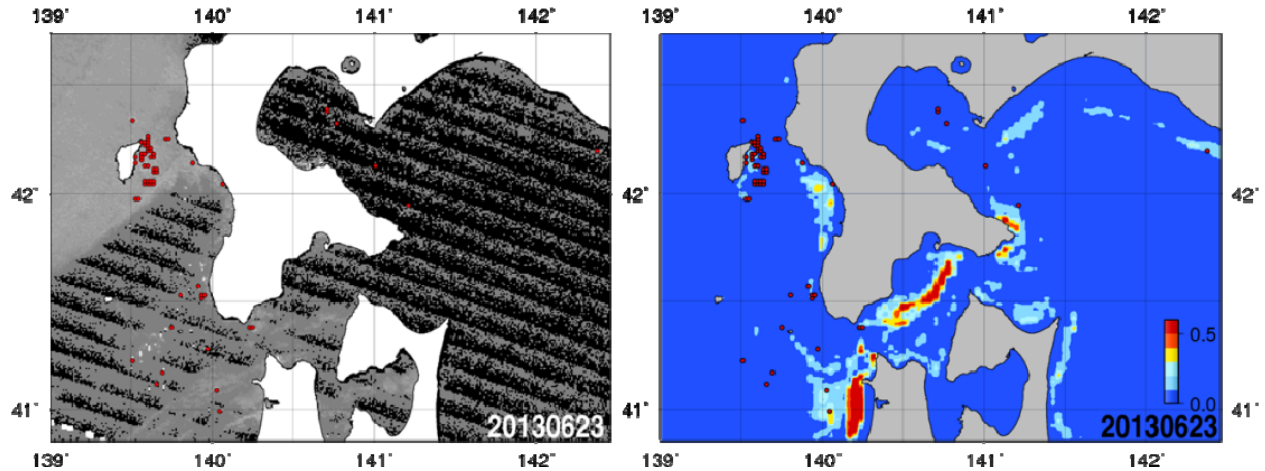


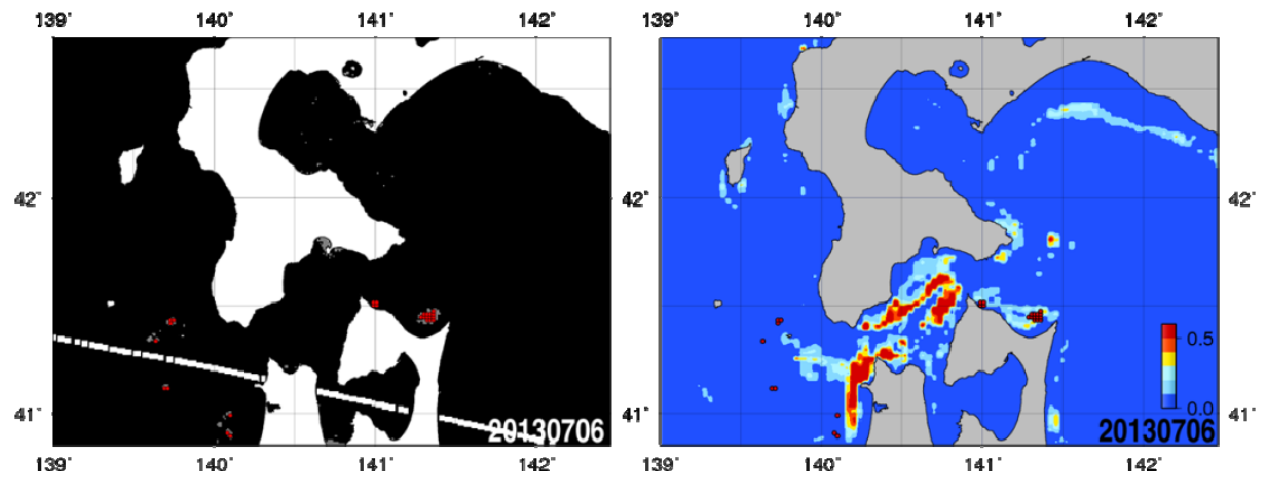
Figure 2. The process chart of fishing location extractions and overlap with prediction maps.

Figure 2 demonstrated the process of extracting fishing locations from VIIRS/DNB nighttime visible images and the overlapping with our daily prediction maps.

Most of fishing vessels conducted their fishing activities in or close to our daily predicted high potential fishing zones (Figure 3). Almost all fishing vessels located in Japan Sea region in June and started to move to Tsugaru Strait region in the beginning of July. There were very few fishing activities in the Pacific region. In our prediction maps, there were some spatial and temporal patterns of high potential fishing zones, and those patterns were consistent with the actual fishing locations.



(a) June 23rd, 2013



(b) July 7th, 2013

Figure 3. Examples of VIIRS/DNB images and daily prediction maps

Figure 4 summarized how the ratio of “hit” changes along with time in Japan Sea region and Tsugaru Strait region. Pacific region was not involved because few fishing vessels located in this region in June and July. For the Japan Sea region, more accurate predictions were observed in June, and the ratio thereafter decreased past June. The ratio became relatively higher from the end of June in Tsugaru region. This change was proposed as a result of the eastern movement of main fishing grounds from the end of July. More fishing activities moved to Tsugaru Strait region in July and this pattern is also consistent with our prediction maps.

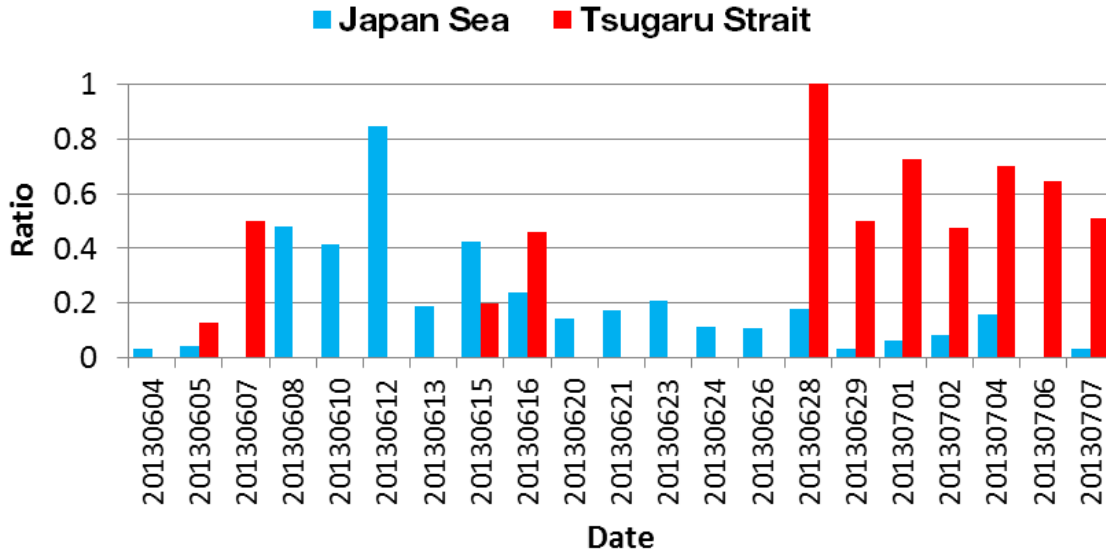


Figure 4. Ratio of vessels' occurrences with high prediction values (>0.1), derived from the overlap between NPP/VIIRS data and our prediction maps (Japan Sea and Tsugaru Strait)

We prepared our four-day prediction maps in color and gray scale versions for ease of visualization and delivering to local fishermen (Figure 5). Useful information on ocean environment was also included. Fishermen received this information every morning before they set off for fishing. According to the feedbacks from local fishermen, our prediction maps really help them in determining fishing locations.

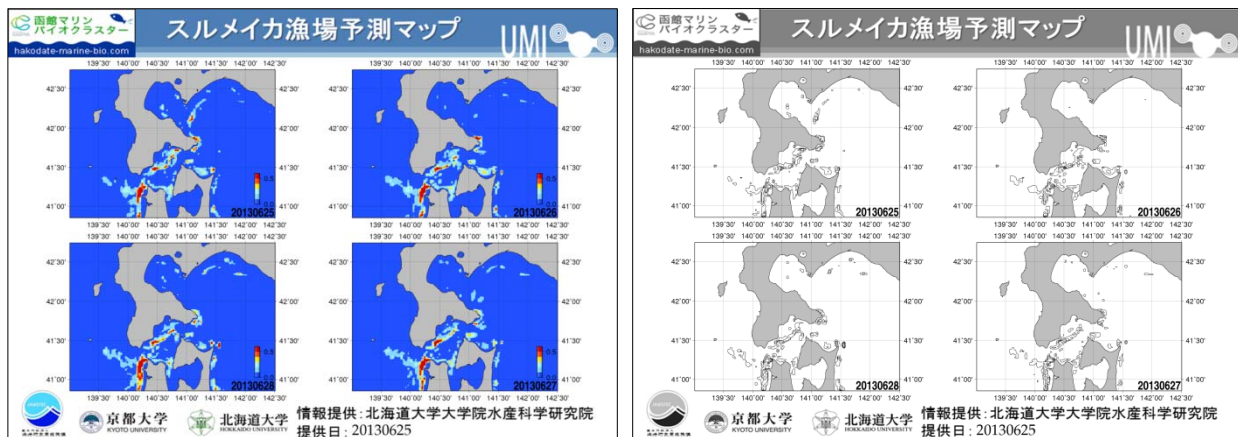


Figure 5. The prediction maps we sent to fishermen on June 25th, 2013

(Color and gray scale versions)

4. Conclusions

Predictive performance was way improved by using 4D-VAR dataset compared to satellite-based information. Predictions based on model-derived data have no weather restriction and making the practical applications of daily prediction more appropriate and feasible.

The “day-night band” of NPP/VIIRS was proved to be very useful for validating our prediction maps as it has better capacity of identifying squid fishing vessels, especially during the summer season when the DMSP/OLS images are not suitable for detecting fishing vessels. In the future, as long as more DNB data are available for model building, potential fishing zones predictions of Japanese common squid can be highly improved.

The practical use of our prediction maps can assist fishermen in maximizing their benefits. Such cooperation with local fishermen does not only improve our prediction model based on their feedbacks, but also promote the development of sustainable use of marine resources and raise awareness on issues on environmental changes.

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