ESTIMATION OF NUMBER OF PACIFIC SAURY FISHING VESSELS USING NIGHT-TIME VISIBLE IMAGES

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ABSTRACT

Pacific saury, *Cololabis saira*, a commercially important species for multi-national fishing fleets in northwestern Pacific is fished using bright lights to attract schools. The lights are easily monitored using night-time visible images from Defence Meteorological Satellite Program/Operational Linescan System (DMSP/OLS). Modeling the relationship between fishing light distribution and numbers of fishing vessels can facilitate near-real time prediction and management of saury fisheries. The objective of this study was to estimate the numbers of fishing vessels from night-time images and landing data in northwestern Pacific coast. Analysis was conducted in ArcGIS. Results show that spatial fishing light distribution is significantly related to numbers of fishing vessels. For instance, in September from 2003 to 2006, the number of emitted pixels was significantly correlated to number of fishing vessels. We suggest that it is possible to estimate fishing effort from remotely sensed night-time visible images.

1. INTRODUCTION

Pacific saury (*Cololabis saira*) is one of the most important commercial fishes in the northwestern North Pacific, especially around the central Kuril Islands, southeastern Hokkaido and northeastern Honshu (Fukushima, 1979). Hatanaka (1955) reported that the saury populations are distributed in three more or less geographically separated areas: the Pacific Ocean, the Sea of Japan and the Sea of Okhotsk. In Japan, the saury fishermen employ stick-held dip net, known as *bouke ami* in Japanese language, which is equipped with lights to attract the fish (Fukushima, 1979). In general, Pacific saury exhibit a north-south seasonal migration pattern in the western North Pacific (Fig. 1). In spring and winter, spawning grounds are formed in the south, off the east coast of Honshu while feeding grounds are in the Oyashio area in summer. Fishing grounds form off the east coast of Hokkaido as saury migrate from the Oyashio area to the south through the Oyashio front in the autumn for spawning (Kosaka, 2000, Tian et al., 2009).

Recently, satellite remote sensing has been utilized as an important tool for obtaining synoptic measurements of the ocean. Satellite data have been applied to study the relationship between oceanographic conditions and the distribution of pelagic fishes (Saitoh et al., 1986; Sugimoto and Tameishi, 1992; Semedi et al., 2002). Using the OLS-VNIR (Operational Linescan System- visible-near infrared) band of DMSP (Defence Meteorological Satellite Program) satellite, it is possible to detect clouds illuminated by moonlight, and lights from cities, towns, industrial sites, gas flares, and ephemeral events, such as fires and lightning-illuminated clouds (Elvildge et al., 1997). Fishing boats which are equipped with lights during fishing activities can also be detected by the OLS sensor. The fishing fleet lights can be identified by night light images generated by the DMSP/OLS sensor. Regarding DMSP/OLS satellite image observations, Cho et al. (1999) reported that a clear relationship between the locations of fishing fleet lights and the Sea Surface Temperature (SST) distribution was observed in an overlaid image between the DMSP/OLS-VNIR image and the DMSP/OLS-TIR (Thermal Infrared) image. Since fishing boats of Pacific saury use light during their operation, it is possible to observe the distribution of the saury fishing fleets using DMSP/OLS-VNIR images. The objective of this study was to estimate the numbers of fishing vessels from night-time images and landing data in northwestern Pacific coast.

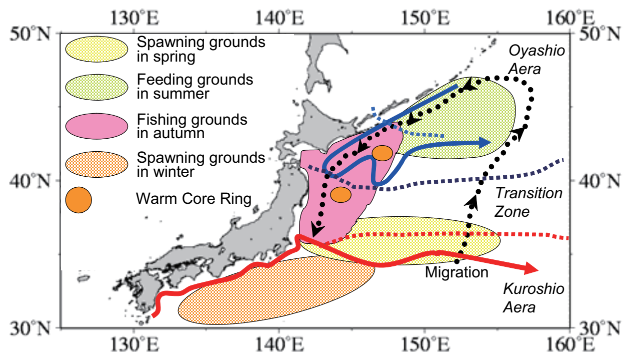

Figure 1. Migration pattern of Pacific saury (after Tian et al. 2003).

2. MATERIAL AND METHODS

2.1 DMSP/OLS satellite data

DMSP satellites are a series of weather satellites operated in a near-polar sun synchronous orbit at a height of about 850 km and provide global coverage roughly twice daily. The DMSP/OLS has a ground swath of about 3000 km. It has two broad spectral bands; one covering the VNIR region (0.5 - 0.9 µm) and the other is in the TIR region around 10 µm. The DMSP/OLS data are acquired in two spatial resolution modes: fine and smoothed. The full resolution fine data have a nominal spatial resolution of 0.56 km. The smooth resolution mode is generated toward averaging five by five blocks of fine data onboard, with nominal spatial resolution of 2.7 km. Pixel values of TIR vary from 190 to 310 Kelvin in 256 equally spaced steps, while visible pixels values range from 0 to 63 (Elvildge et al., 1997). DMPS/OLS data from 2003 to 2009 were downloaded from the Satellite Image Database System in MAFF (SIDaB) (http://www.sidab.agropedia.affrc.go.jp/SIDaB/index.php).

We employed the TeraScan Sea Space system and ArcGIS/Spatial Analyst as GIS tools to process the images. The DMSP/OLS raw data were transformed into Rectangular projections to obtain images with a resolution of 1.1-km in the western North Pacific (33°-48°N; 140°- 156°E).

2.2 Landing data of Pacific saury

Coastal fishing grounds are generated off Kushiro in north-eastern Hokkaido. The distance between fishing ports along north-eastern Hokkaido coast and fishing grounds is not so large and can be covered by about half a day's steaming. In practice, vessels are capable of fishing off the coast at night and landing their catches at the fishing ports the following morning. With this knowledge, we considered the catch landed on a particular morning to have come from vessels fishing offshore the previous night. Consequently, we counted the number of vessels landing their catches on a specific date and related them with the distribution of lights detected by DMSP/OLS images in the previous night. We chose four fishing ports along the north-eastern Hokkaido, Kushiro, Akkeshi, Hamanaka, and Hanasaki (Nemuro) in September from 2003 to 2009.

2.3 Estimation of the number of fishing vessels

We examined the relationship between landing data at the four fishing ports and the total number of pixels of Pacific saury fishing vessels in September from 2003 to 2006. Hara et al. (2004) defined digital number of DMSP/OLS visible channel for Pacific saury fishing vessels with maximum light power of 600 kW using the linear equation Y = 12.612*X + 9.3668 where Y is light power and X is the DN (Digital Number of OLS). We used a threshold value is 46.8 for detecting Pacific saury vessels. From this information we developed a model to estimate the number of Pacific saury fishing vessels. The dataset from 2007 to 2009 was used to validate this equation. We defined density of fishing vessels as the number of fishing vessels per fishing area per day (Stelzenmuller et al., 2008).

3. RESULTS AND DISCUSSION

3.1 Validation of estimation equation

We examined the relationship between landing data and the total number of pixels of Pacific saury fishing vessels in September from 2003 to 2006 using relatively could free DMSP/OLS data. As a result, we obtained equation (1) using all data as shown in Figure 2. When using all the data, there was some overestimation due to sun glittering during the early hours of the evening just before sunset. When we selected data after 7:30 PM, we obtained equation (2) (Figure 3).

$$N_{vessels} = 42.918 \, \mathrm{Ln}\,(N_{pixels}) - 118.4 \qquad (1)$$

$$N_{vessels} = 48.446 \, \mathrm{Ln}\,(N_{pixels}) - 156.9 \qquad (2)$$

where $N_{vessels}$ = Number of vessels
N_{pixels} = Number of pixels

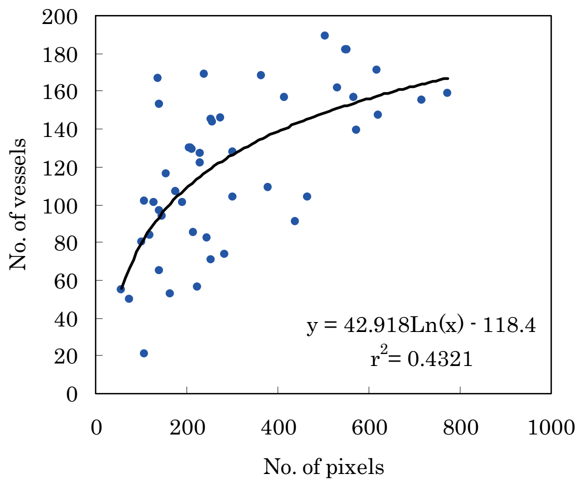

Figure 2. Relationship between number of pixels and number of vessels (all data)

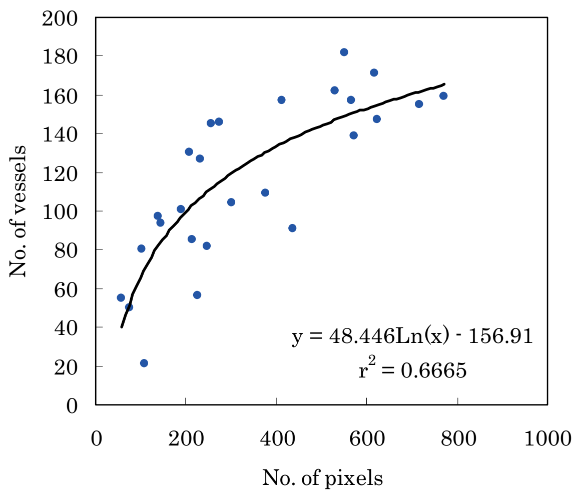

Figure 3. Relationship between number of pixels and number of vessels (data after 7:30 PM)

Our results are similar to those obtained with squid vessels (Waluda et al., 2002). Therefore, we employed equation (1) in estimating the number of fishing vessels at anytime of the night and equation (2) as a more precise model which estimates numbers of fishing vessels after 7:30PM. From these two models (equations) we deduced that fishing activities most likely start after 7:30PM in September. The maximum number of estimated fishing vessels is around 180 and this value is consistent with a report which describes numbers of licensed Pacific saury fishing vessels as ranging from 170 to 220 from 2003 to 2006 (TNFRI, 2008). Consequently, our models can be said to show the upper limit of the total number of fishing vessels. The exponential curve shows that the relationship between numbers and spatially distributed lights (aggregation pattern) of Pacific saury vessels compared with squid vessels is not linear.

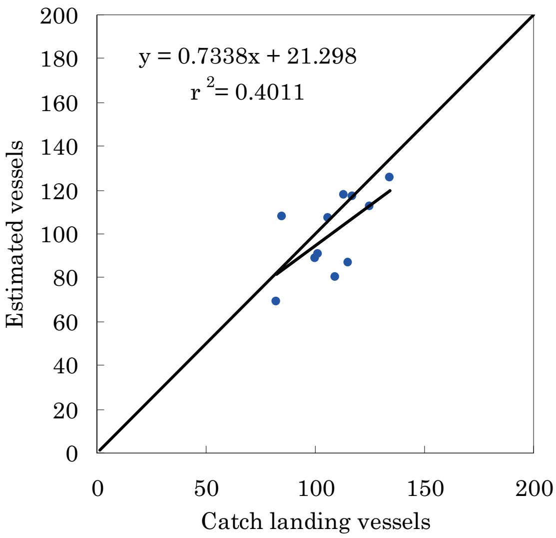

Figure 4. Scatter plot between existing vessel number and estimated vessel number using equation (1).

Relatively early before 7PM, there were many overpasses in September from 2007 to 2009, so we employed equation (1) for validation of estimated number of vessels. Figure 4 shows a relatively good correlation between existing fishing vessel numbers and estimated fishing vessel numbers with r^2=0.4 ($p<0.0001$, n=11).

3.2 Relationship between density of vessels and landing data

We generated 10 days averaged dataset for both landing (catch) and density of vessels. Figure 5 shows a negative relationship between catch and density of vessels with r^2=0.6542 ($p<0.0001$, n=8). This result shows that catch increases when density of vessels is low. Therefore, dispersion of fishing vessels is inversely related with catch when the distance between vessels is over 2.5 km.

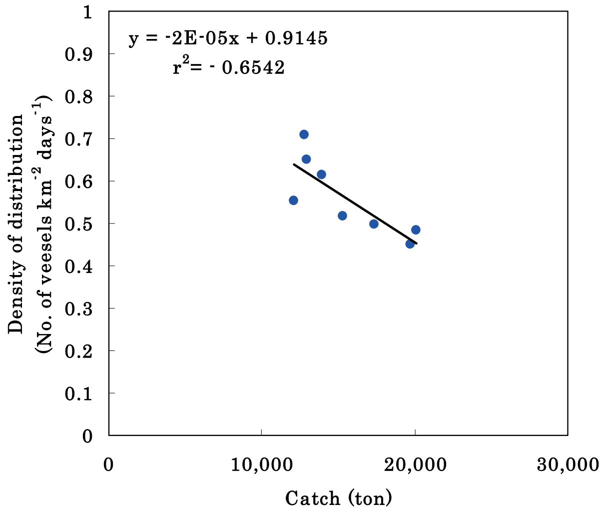

Figure 5. Relationship between catch and density of fishing vessels in September from 2003 to 2006.

3.3 Interannual variation of density of vessels and catch

When we compared annual mean CPUE (Catch Per Unit Effort) with monthly mean density of fishing vessels in September from 2003 to 2006, high CPUE year corresponds to low density of vessels in 2006 and low CPUE year corresponds to high density of vessels in 2003 (Figure 6). This shows an inverse relationship between fishing vessel density and CPUE where low vessel densities reflect an increase in CPUE. On the other hand, higher vessel densities may result in a low CPUE, especially in cases when the fishing ground formation is maintained for a relatively long period.

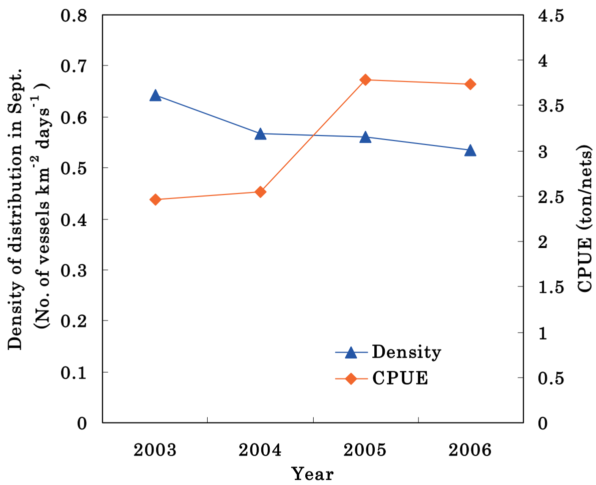

Figure 6. Interannual variation of CPUE and density of fishing vessels.

4. CONCLUDING REMARKS

Results show that spatial fishing light distribution is significantly related to numbers of fishing vessels. For instance, in September from 2003 to 2006, the number of emitted pixels was significantly correlated to number of fishing vessels. We suggest that it is possible to estimate fishing effort from remotely sensed night-time visible images. Further research in this field can improve our understanding of fishing ground formation and distribution. The information is also relevant for effort control and management.

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