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ASSESSING DISTRIBUTION PATTERN FOR SKIPJACK TUNA IN BONE GULF, INDONESIA DURING JANUARY-JUNE

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ABSTRACT

Satellite remote sensing provides systematically important information on oceanographic signatures. Sea surface temperature (SST) and chlorophyll-a concentration (Chl-a) obtained from Aqua/ Moderate Resolution Imaging Spectro-radiometer (MODIS) data together with skipjack fishing data during January-June were applied to assess the distribution pattern of skipjack tuna in the Bone Gulf, Indonesia. Geographic information system techniques were employed to map out the potential fishing zone generated from the Cobb Douglass model. The fish distribution pattern was produced by the movement of the Gravity Center of the potential fishing ground. Results expressed that the most potential catch per unit efforts (fish/boat-days) associated with the areas where a combination of optimum SST and chlorophyll-a concentration ranged was found. The center of skipjack potential fishing zones developed in January-February along with the western regions in the Bone Gulf and moved to the northern side during March and April, and subsequently migrated to the south in May –June. We found that skipjack tuna showed a clockwise movement pattern throughout the Bone Gulf during the first semester period (January-June). Therefore, the potential fishing zones suggest corresponding to the movement of skipjack concentration, which may link with prey upon by skipjack.

Keywords: skipjack tuna, distribution pattern, Bone Gulf, satellite data, clockwise movement pattern

INTRODUCTION

Skipjack tuna is the most critical species targeted by the local fishermen in the Bone Gulf, South Sulawesi. The distribution and abundance of this species are strongly influenced by dynamics of marine environmental factors such as distributions of surface temperature and chlorophyll-a density (Zainuddin, 2011). Skipjack migration route and habitat in the Bone Gulf may correspond to the optimum Chl-a and or SST fronts movement (Andrade, 2003; Zainuddin et al., 2017). The 29°C SST isotherm distribution known as the salinity front is a reasonable proxy to detect the region of highest skipjack CPUEs (frontal area) in the western Pacific Ocean (Lehodey et al., 1997; 1998). The highest skipjack CPUEs off the southern Brazilian coast occur in waters of SST 22°-26.5°C, although the optimum range varies seasonally (Andrade and Garcia, 1999).

A combined satellite remote sensing (SRS) and geographic information system (GIS) provide excellent insight and a powerful approach to detect potentially marine fish habitats, particularly for highly migratory species. Important information on oceanographic conditions of both SST and Chl-a can be derived continuously in comprehensive area coverage (Zainuddin et al., 2004). This information will be essential to exploring potential fishing grounds and the distribution pattern of tuna. SST and Chl-a derived from satellite data are determinant factors in predicting tuna forage and their habitat in the Western North Pacific Ocean (Polovina et al., 2001; Zainuddin et al., 2008). Therefore, the objectives of this study are to assess the relationship between oceanographic factors and skipjack tuna abundance and predict potential fishing zones and movement patterns using a statistical model and a combination of SRS data and GIS techniques.

MATERIALS AND METHODS

The physical and biological environmental data used to explain the oceanographic signatures at the fishing areas were SST and Chl-a data derived from Aqua/MODIS. NASA distributes Standard Mapped Image (SMI) level three binary data with HDF (Hierarchical Data Format/ netCDF) format (https://oceancolor.gsfc.nasa.gov/). We used the satellite data with the monthly temporal scale, January-June 2007, and 0.044° of longitude and latitude spatial resolution. We processed the data using SEADAS (SeaWiFS Data Analysis System) software package to get/cut image data throughout the study area. The pole and line fishery data consisted of fishing ground positions in latitude and longitude derived from GPS, SST fishing boat, and daily CPUE data. We compiled the monthly daily data to match the satellite data temporal resolution. The oceanographic data were linked to fishery data to estimate and extract SST and Chl-a at and around fishing grounds using spatial analyst in GIS.

In this study, firstly, we plotted the fishing data on SST and Chl-a image maps to understand the spatial and temporal distribution pattern of skipjack fishing grounds relative to the oceanographic conditions. Using the non-linear regression model (Cobb Douglas model), we then investigated the relationship between the oceanographic conditions of SST and Chl-a and catch data. The significant model produced by this relationship was used to predict potential fishing zones (hereafter PFZ) for skipjack throughout the study area every month from January to June 2007. The migration pattern of skipjack was determined by computing the latitudinal and longitudinal gravity center of fishing ground (GCF) according to Lehodey et al. (1997). The GCF was calculated for all image maps grid data with predicted values of more than percentile 95. We consider that the movement of the GCF within the potential fishing zone map every month reflects the trend of skipjack concentration on average, which in turn describes the distribution pattern of skipjack tuna in the Gulf of Bone, Indonesia. All images produced in this study were mapped using ArcGIS 10x and Generic Mapping Tools (GMT) software packages.

RESULTS AND DISCUSSION

Figures 1 and 2 showed spatial distribution of all skipjack fishing locations overlain on Chl-a and SST imageries, respectively, during January-June 2007. In January, high catch skipjack fishing grounds occurred in the western part of Bone Gulf, to be exact, near Sinjai coast. Along with the west Gulf from Sinjai to Bone coastal areas, skipjack fishing grounds are well developed in good association with Chl-a of 0.2-0.3 mg m^{-3} and SST of 30-30.5°C. During this month, the highest CPUEs also tended to concentrate in the northern area, near Luwu coast, where the fish occupied areas of 0.2-0.3 mg m^{-3} chlorophyll concentration and at 31°C SST isotherm. The productive fishing areas have a distance from Sinjai and Luwu fishing bases of about 20-30 km and 35-40 km, respectively. The SST and Chl-a maps in February exhibited that the distribution of skipjack fishing grounds in Sinjai coastal waters (known as the A area) was associated with 29-30°C SST and relatively low chlorophyll concentration (≤ 0.2 mg m^{-3}) and had spatial distribution pattern almost similar with the previous month. This month, skipjack fishing grounds developed in the northern area (Luwu coastal waters known as B area) corresponded with 31.5°C SST isotherm and 0.3 mg m^{-3} Chl-a isopleth. Skipjack CPUEs in this month were higher than in January, probably linked to warmer SST (Lehodey et al., 1997) and relatively suitable Chl-a (Zainuddin et al., 2017).

The distribution pattern of skipjack fishery in March was almost the same as that in April. Skipjack CPUEs in these months tended to be higher than in the two previous months. It may increase SST and Chl-a in the northern side, stimulating good feeding opportunities (Polovina et al., 2001; Mugo et al., 2010). In March, the image maps showed that skipjack catches were primarily found in A area where SST and Chl-a were about 30.5-31°C and 0.15-0.20 mg m^{-3}, respectively. The highest CPUEs in the B area were mainly obtained in 31-31.5 °C SST waters and 0.15-0.2 mg m^{-3} Chl-a density. In April, for the area of the southern Bone Gulf (A area) skipjack CPUEs tended to aggregate in a similar distribution pattern and Chl-a concentration and SST condition in March. Whereas in the northern part of Bone Gulf (B area) for this month, the fish concentrated in a very narrow latitudinal band with SST near 31.5°C and Chl-a ranged from 0.3 to 0.4 mg m^{-3}.

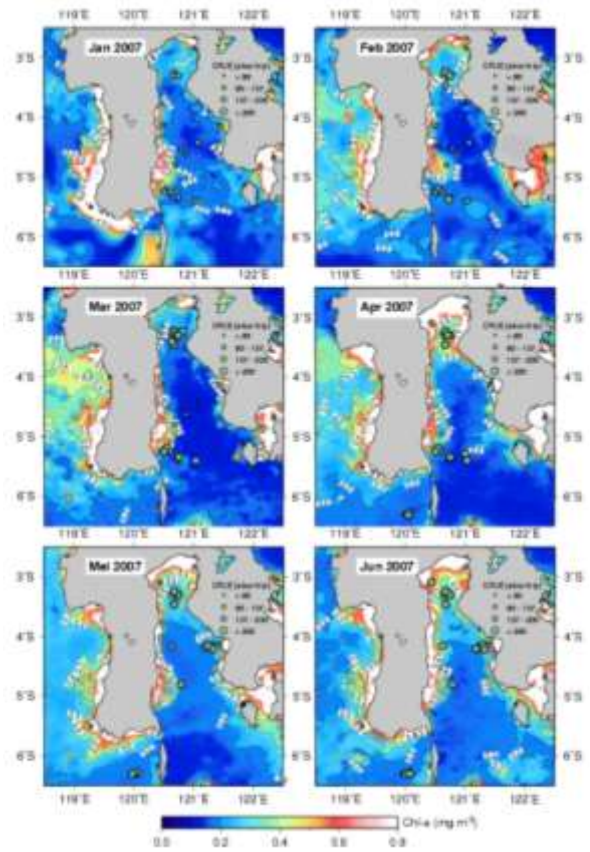

Figure 1. The Spatial Distribution pattern of Skipjack CPUE (fish/Fishing-Boat Days) From Pole and Line Fishery Superimposed on MODIS Chl-a Images From January to June 2007.

During March-April skipjack catches in B area increased significantly, implying that the fish concentrations moved to the north during the period. In May and June, there were two main productive fishing grounds, i.e, B area and the eastern area of Bone Gulf (Kolaka coastal waters known as C area). Satellite data in May indicated that tuna concentrate in B and C areas in waters of 30.5-31.0°C SST and 0.20-0.30 mg m-3. In June skipjack fishing grounds remain well-formed in the two productive fishing areas. The highest CPUEs are associated with 30.5°C SST isotherm and 0.3 mg m^{-3} Chl-a isopleth in B or C. It is clear that skipjack migrates southeastward of the Bone Gulf during May-June along with the best indicator of Chl-a (Zainuddin et al., 2017; Hidayat et al., 2021).

The frequency of fishing days (trip) in relation to both SST and Chl-a derived from satellites showed specific ranges where skipjack tend to concentrate (Fig.3).

Skipjack fishing grounds occurred in areas and periods where SST ranged from 28.5 to 32.5°C, and Chl-a ranged from 0.15 to 0.75 mg m-3. However, most of the catches were obtained in waters where SST and Chl-a varied from 29.5 to 31.5°C and from 0.15 to 0.35 mg m^{-3}. Hasil ini diperkuat oleh hasil penelitian sebelumnya (eg. Putri et al., 2018). Our preliminary study found that the relationship between SST fishing boats and SST satellite data was statistically significant (P <0.0001, n=460 sampling data). Therefore, we used SST satellite data together with Chl-a as input data on the prediction model to generate potential fishing zones for skipjack in the Gulf of Bone.

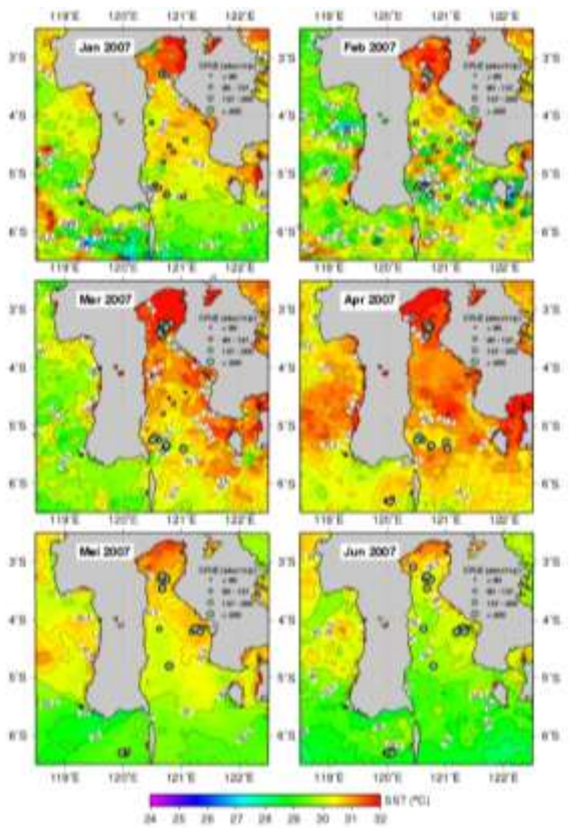

Figure 2. The Spatial Distribution of Skipjack CPUE (fish/Fishing Days) From Pole and Line Fishery Plotted on MODIS SST Images for January - June 2007.

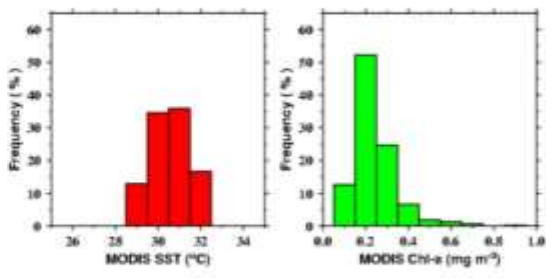

Figure 3. Skipjack Fishing Frequency concerning MODIS SST (Left) and Chl-a (Right), during January-June 2007.

The PFZ maps for skipjack tuna predicted by a non-linear regression model are shown in Figure 4. Analysis of variance indicated that the model was significant (P<0.0001), and all predictor variables (SST and Chl-a) were significant in a Student's t-test. In January, the PFZ for skipjack formed in the western area near Sinjai and Bone coastal waters (A area) at approximately 120-120.5°E and 4-4.5°S. This month, it moved to the north, and the PFZ developed continuously in the B area from February through March. The PFZ was most set in April in the northern part of the Bone Gulf (near B area). Skipjack abundance continuously moved from A to B area during this month, and the enhanced PFZ appeared to form.

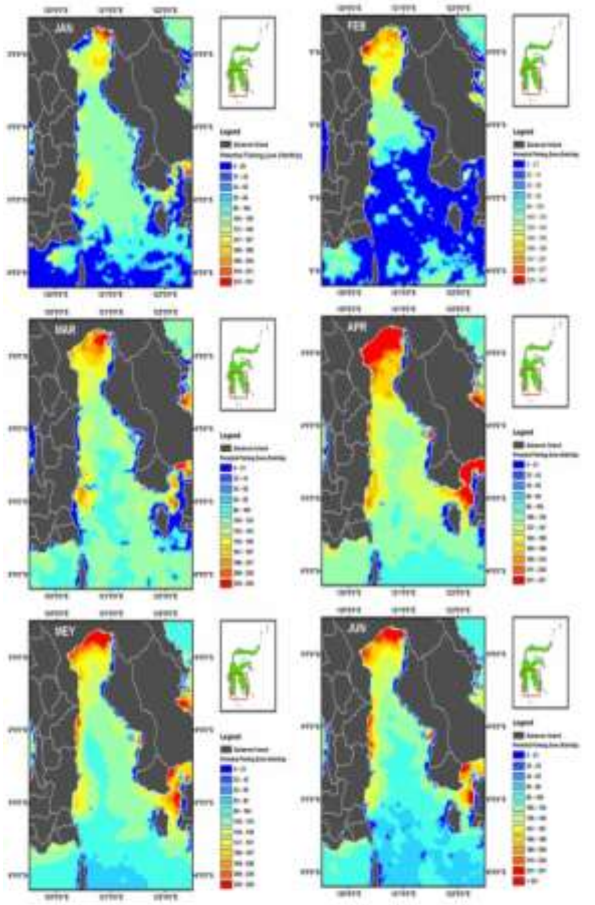

Figure 4. The Spatial Distribution of Potential Fishing Zones (fish/Fishing-Boat Days) for Skipjack tuna Produced By Non-Linear Regression Model From January to June 2007.

In this paper, we consider that potential fishing zones (PFZ) influence catch rates for skipjack. The PFZ represents the areas where preferred environmental conditions encourage high skipjack tuna concentrations. The high CPUEs are produced when pole and line fishing gear operates at and around the PFZ, which otherwise are less productive. Pole and line CPUE can be regarded as an index of relative abundance for tuna (Bertrand et al., 2002), so this study has assumed that the CPUE represents the relative abundance of skipjack in the study area (Bone Gulf). Based on the dynamic movement of the PFZ during January-June, it is most probably that the fish tend to experience a clockwise distribution or movement pattern in the Bone Gulf (Fig.5). The dynamic Spatio-temporal distribution trend is significant to developing fishing strategy and conservation management in the study area (Amir and Mallawa, 2015).

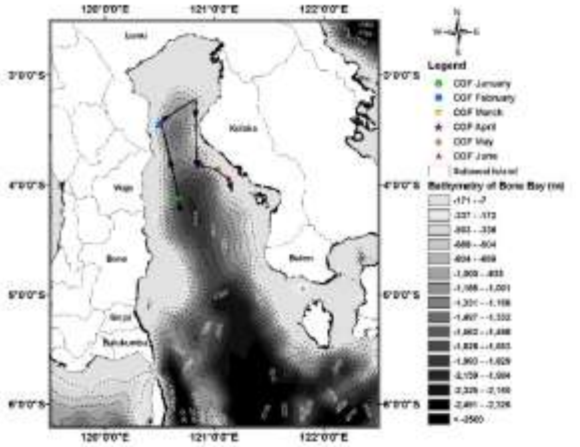

Figure 5. Description of Movement Pattern of Skipjack Tuna Produced By The Center Gravity of Predicted Potential Fishing Zones during January-June 2007 in the Bone Gulf, Indonesia.

Local fishers may rely on previous experience and knowledge when they move to a fishing ground and search for suitable oceanographic conditions such as SST for conducting fishing operations. Although it seems that there is a non-random distribution of skipjack fishery, we thought that the specific oceanographic conditions and selected space-time fishing locations that the fishermen look for probably correspond to real situations of dynamic abundance and vulnerability of skipjack. Considering these points, we assumed that the fisheries data represent the natural variability of skipjack distribution and abundance in relation to oceanographic conditions of the Bone Gulf.

CONCLUSIONS

Using satellite-based environmental data, we mainly found that the most potential catch abundance associated fairly with the areas of an optimum combination of SST and Chl-a. The center of tuna potential fishing zones developed in January-February along with the western Bone Gulf and shifted to the northern area during March and April, and subsequently migrated to the south from May to June. Skipjack tuna showed a clockwise movement pattern throughout the Bone Gulf during the first semester period (January-June). It suggests that the potential fishing zones appear corresponding to the dynamics movement of skipjack schools, which are likely to link with prey abundance.

REFERENCES

Amir, F., & Mallawa, A. 2015. Pengkajian Stok Ikan Cakalang (Katsuwonus pelamis) di Perairan Selat Makassar. Jurnal IPTEKS Pemanfaatan Sumberdaya Perikanan, 2(3): 208-217.

Andrade, H.A. and A.E. Garcia. 1999. Skipjack tuna in relation to sea surface temperature off the southern Brazilian coast. Fish. Oceanography 8(4):245-254.

Andrade, H. A. 2003. The relationship between the skipjack tuna (Katsuwonus pelamis) fishery and seasonal temperature variability in the south-western Atlantic. Fisheries Oceanography. https://doi.org/10.1046/j.1365-2419.2003.00220.x

Hidayat, R., M. Zainuddin, M.A Mustafa, A. Mallawa and R.S. Putri. 2021. Mapping spatial-temporal skipjack tuna habitat as a reference for Fish Aggregating Devices (FADs) settings in Makassar Strait, Indonesia. Biodiversitas, 22(9): 3637-3647.

Lehodey, P., Bertignac, M., Hampton, J., Lewis, A. and Picaut, J. 1997. El Niño southern oscillation and tuna in the western Pacific. Nature 389:715-718.

Polovina, J.J., Howel, E., Kobayashi, D.R. and Seki, M.P. 2001. The transition zone chlorophyll front, a dynamic global feature defining migration and forage habitat for marine resources. Progress in Oceanogr. 49:469-483.

Mugo, R., S.-I. Saitoh, A. Nihira, and T. Kuroyama. 2010. Habitat characteristics of skipjack tuna (Katsuwonus pelamis) in the western North Pacific: a remote sensing perspective. Fisheries Oceanography. https://doi.org/10.1111/j.1365-2419.2010.00552.x

Putri, R. S., Jaya, I., & Pujiyati, S. 2018. Survei Keberadaan Ikan Cakalang Katsuwonus Pelamis di Teluk Bone. Jurnal Ilmu dan Teknologi Kelautan Tropis, 10(1), 69-78.

Zainuddin, M., K. Saitoh and S. Saitoh. 2004. Detection of potential fishing ground for albacore tuna using synoptic measurements of ocean color and thermal remote sensing in the northwestern North Pacific. Geophysical Research Letters, 31, L20311, doi:10.1029/2004GL021000.

Zainuddin M. 2011. Skipjack tuna in relation to sea surface temperature and chlorophyll-a concentration of Bone Bay using remotely sensed satellite data. Jurnal Ilmu dan Teknologi Kelautan Tropis 3 (1): 82-90. DOI: 10.29244/jitkt.v3i1.7837.

Zainuddin, M., A. Farhum, S. Safruddin, M. B. Selamat, S. Sudirman, N. Nurdin, M. Syamsuddin, M. Ridwan, and S. I. Saitoh. 2017 Detection of pelagic habitat hotspots for skipjack tuna in the Gulf of Bone-Flores Sea, southwestern Coral Triangle tuna, Indonesia. PLoS ONE 12(10): 1–19. https://doi.org/10.1371/journal.pone.0185601.