Omni-Akuatika, 14 (1): 1–10, 2018
ISSN: 1858-3873 print / 2476-9347 online
Research Article

journal homepage: http://ojs.omniakuatika.net

Sea-Air Impacts on Fishing Season of Hand Line Skip Jack Tuna *Katsuwonus pelamis* (Linnaeus, 1758) in Southern Pacitan Waters, East Java-Indonesia

Bram Setyadji[1], Widodo S. Pranowo[2,4] and Khairul Amri[3]

[1)] *Research Institute for Tuna Fisheries, Jl. Mertasari No. 140, Sidakarya, Denpasar, Bali 80224*
[2)] *Marine & Coastal Data Laboratory, Marine Research Center, Jl. Pasir Putih 1, Ancol Timur, Jakarta 14430*
[3)] *Research Institute for Marine Fisheries, Jl. Muara Baru Ujung, Jakarta 14440*
[4)] *Indonesian Naval Postgraduate School (STTAL), Jl. Pantai Kuta No. V, Ancol Timur, Jakarta 14430*

Corresponding author: bramsetyadji@gmail.com

ABSTRACT

Fishing season is important in term of understanding the catch dynamics however, by far the analysis never considered environmental variables into the calculation. The environmental variables in this case is addressed to sea-air interactions during 2012-2015, i.e. monthly wind, surface wind wave, and precipitation level. This study aimed the alternative, yet breakthrough on using Generalized Linear Model (GLM) to analyze the fishing season of skipjack tuna caught by small-scale hand line fleet. The result showed that GLM can be a good alternative in term of predicting the fishing season of skipjack tuna. It provided a good understanding with the surrounded environmental variables. Skipjack tuna fishing season starts from March, reach its peak in April and October. The low season is Februari, June and September. Local weather (wind speed) and religious affair (Fast Ied) significantly affected the fishing behavior thus lead to dynamics of CPUE obtained.

Keywords: sea-air; fishing season; hand line; skipjack; GLM; small-scale

1. Introduction

Skipjack tuna (*Katsuwonus pelamis*) has become the target species for small-scale fisheries for decades (Fonteneau et al*.,* 2013). It mostly exploited by coastal countries along the Indian and Pacific Ocean. However, in the last 30 years the catch of skipjack in Indian Ocean has increased substantially, which largely been driven by the arrival of purse seiners and Fish Aggregating Device (FADs) in the 1980s (IOTC, 2016; Dueri *et al*., 2012). The catches of skipjack tuna from Indonesian fleets were accounted for 21% from total catch in Indian Ocean (IOTC, 2016). The average catch from 2011-2015 estimated to be around 81,733 metric ton. It mainly contributed by coastal purse seine, hand line and pole and line fisheries. Unlike the declining trend reported by Maldivian fishery (Adam et al., 2012), the catch of skipjack from Indonesian fleets are increasing over the years (Irianto et al., 2016). However, the catch should be close-monitored as a precautionary approach, even though skipjack tuna is considered to have a high resilience against overfishing due to their fast growth rate and their year-round spawning (Dueri et al., 2012).

In order to maintain the catch in a sustainable condition, several conditions related to the fishery must be understood, before applying any management measures. One of which is fishing season, because it resembles catch dynamics during a fishing year. Fishing season can be determined by several approaches. The simplest method is using catch as a base calculation as proposed by Mertha et al (2004). It simply divides between average monthly catch of a target species with average monthly catch of all species, and then subtract it by 1. The highest value occurred was

http://dx.doi.org/10.20884/1.oa.2018.14.1.207

placed as a base for assumption for seasonal catch. This method was used to explain the fishing season in hand line tuna and skipjack fishery in Pondokdadap, Malang (Nurdin and Nugraha, 2008) and purse seine small pelagic fishery in Banda Sea (Hariati, 2011).

The second method is using moving average of catch per unit of effort (CPUE) based on time series data which proposed by Spiegel (1961) and later slightly modified by Dajan (1983). This method was used to explain the fishing season of small-scale skipjack fishery in Bengkulu waters (Zulkasyni, 2014), Prigi waters, East Jawa (Setiyawan et al., 2013), Belang waters, South East Minahasa, North Sulawesi (Kekenusa dan Paendong, 2016) and Kepala Burung waters, Papua (Tilik et al., 2014). However, all aforementioned methods might contain biases because fishing season is not solely dependent on the effort nor the quantity of the catch, but other factors, i.e. socio-cultural (fishing behavior) of fishermen along south Java coasts which closely related to sea-air interactions (Pranowo et al., 2016). The main variables are sea surface temperature (SST), chlorophyll-a, seasonal wind, surface wind wave and precipitation level. Both SST and chlorophyll-a are not discussed in this study. Surface wind during June – October generating a semi-permanent Java coastal upwelling events (Pranowo et al., 2005; Pranowo, 2014; Utamy et al., 2015;). During these periods, surface wind will also generate significant wave height. Those (wind) waves and its combination with precipitation level may be a limiting factor to the small-scale fishing trips and lower catches in months. Religious affair FastIed, which is happening in August (2012-2013) and July (2014-2015), are suspected can be also as limiting factors. In order to accommodate all those variables, a more robust method or model should be further investigated.

The sea-air variables selected in this study were not intended to investigate its effect on catch, but instead focused on how fishermen respond to the condition. The variables are led to the decision whether they will go fishing or not, which become the main objective of this study. Pacitan fishing port was chosen because it considered as one of the largest small-scale tuna landing in East Jawa, aside of Sendang Biru, Malang and Prigi, Trenggalek. It also recognized for having a good, structured time series landing data compared to others. We believe the results are valuable in term of standardize the method for determining the fishing season in small-scale fisheries.

2. Materials and Methods

2.1 Fishery data

A total of 2,758 catch and effort data of hand line fleets were obtained from daily landing activity in Pacitan fishing port from May 2012 to December 2015. The number of positive trips were 2,329 (84.45%) and the percentage of zero catch per trip around 15.55% (429 trips). The unit of effort unit for hand line fleet is “days at sea”, while catches are in weight (kg). The small-scale tuna fishermen using various modification of hand lines, thus the term “hand line” in this study represents all the gears using lines (monofilament/nylon), swivels, hooks and bait as the main configuration. It also operated manually by hands during setting and hauling. The fishing ground, as represented by the Fish Aggregating Device (FAD) was stretch from Pacitan’s coastal area to Indonesian Exclusive Economic Zone (EEZ), between 8-12 ^{o}S to 110-114 ^{o}E (Figure 1).

2.2 Environmental data

All the sea-air parameter data used in the model, such as: precipitation level, wave height and wind speed were compiled and extracted by Marine and Coastal Data Laboratory, Marine Research Center, Indonesian Ministry of Marine Affairs and Fisheries. The source of the data for precipitation level (millimeter) and wind speed (m/s) data was generated from National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis, National Oceanic and Atmospheric Administration (NOAA), Earth System Research Laboratory. As wave height data (meter) was extracted from AVISO+ Satellite Altimetry Data with restrictions coordinate 8-12 °S and 110-114 °E. While for precipitation level (mm) and wind speed (m/s) were restricted at coordinate point 7.5 °S and 110 °E as the closest station from Pacitan fising port. Pearson’s pairwise test was used to investigate any collinearity between environmental variables. Map was drawn using QGIS version 2.12. The world map was acquired from Natural Earth (http://naturalearthdata.com), while EEZ boundaries and bathymetry map were courtesy of Claus et al. (2017) via http://marineregions.org. A Pearson’s product-moment correlation coefficient was computed to assess the relationship (multicollinearity) between environmental variables.

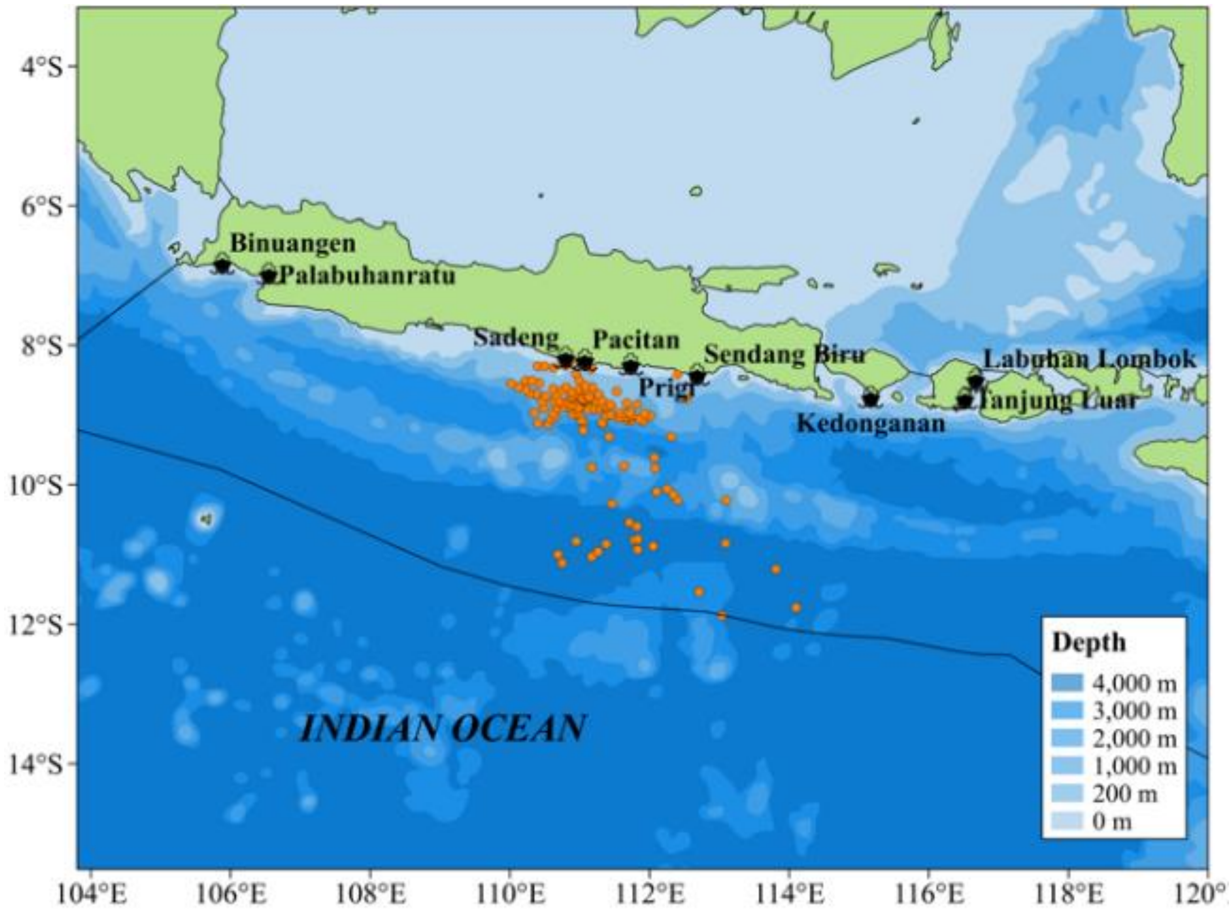

Figure 1. Known fishing of hand liners targeting skipjack tuna (represented by FADs location) was stretch from Pacitan's coastal area to EEZ boundaries.

2.3. Predicting CPUE by environmental factors

The fishing season was predicted as a standardized (relative abundance) of CPUE on each month using mathematical model. Generalized linear models (GLM) was chosen because it can incorporate many variables that might affect the behavior of small-scale tuna fishing practice. GLM can be written in matrix notation as $g[E(Y)] = X\beta$ where Y is a vector of realizations of the response variable; $E[\,]$ is the expectation function, $g(\,)$ is the link function, β is the vector of parameters and X is the design matrix of the explanatory variables. A probability distribution for Y and a link function need to be selected in advance to calculate estimations of the parameters β, which represent the effects of the explanatory variables (*e.g.* month).

In this study, GLM was used to model the nominal catch rate (kg/days at sea) as response variable. Since skipjack tuna was not the only target species, the model must have the ability to deal with some number of zero catches that might have occurred. Therefore, a Tweedie distribution model was applied in which zero-data can be uniformly handled (Tweedie, 1984). It has the ability to incorporate zero catch data with non-zero catch data into a single model (Candy, 2004). In addition, it also can accommodate larger ranges of models for count data than the Poisson, Negative Binomial, Zero-inflated Poisson and Zero-inflated Negative Binomial models (Minami et al., 2007). The GLM full model is described as follows:

CPUE ~ Year + Month + FastIed + WaveHeight + PrepLevel + WindSpeed + ε

Where:

CPUE	:	Catch per unit of effort (kg/days at sea)
Catch	:	The nominal of skipjack tuna caught per trip (kg)
Days	:	Days at sea
FastIed	:	Months where Ramadhan and Ied Mubarak take place
WaveHeight	:	Daily average wave height (m)

PrepLevel	:	Daily average precipitation level (mm)
WindSpeed	:	Daily average wind speed (m/s)
Month	:	Months in a year
Year	:	Year of observation (2012-2015)
ε	:	the error term (tweedie distribution)

To determine which explanatory variables were to be included in the full model, the simple models were fitted with one variable at a time. The variable providing the model with lowest residual deviance was selected first. As second step the model with the selected variable then received other variables, one at a time, and the model with lowest residual deviance again selected. This procedure continued until deviance did not decrease as new variables were added to the previous selected model.

No interaction was included in the model. Akaike Information Criterion (AIC) (Akaike, 1974) was used to select among models as calculated using different density distributions (gamma and gaussian) and link functions (e.g. logarithm and identity). Pseudo-R^2 was utilized for comparing model for different response variables (catch rate and logarithm of catch rate). Standard diagnostic plots were used to assess the fitting of the selected model. All the analyses were carried out using R software functions version 3.2.4 (R Core Team, 2016).

1. Results and Discussion

a. Results

Fisheries aspect

In general, the mean catch of skipjack is showing strong seasonal pattern and increasing trend from 2012-2015. It ranges from 500-71,624 kg, with average 19,198 kg/month. Higher catch usually occurred during June-July but not in 2013-2014, which occurred during October-November and April-May. This shown how small-scale fisheries is contain a lot of uncertainty. The number of fishing trips per month also seasonal and relatively have a stable pattern (Figure 2).

Sea-air indices

All sea-air variables show a strong seasonal pattern. Strong winds (more than 5 m/s) occurred mainly during January-February and July-August, while weak winds (below 5 m/s) occurred mainly at February-April and October-December. Rain fall all year long. Low precipitation (below 40 mm) occurred August-October, while intense precipitation occurred during November-July (40-50 mm), with remarks that in 2015 the rainy season ended earlier on April. The wave height around the port also shown a seasonal trend even tough in a small range between 1.25-2.25 m. Higher wave could be found during July-September and lower wave occurred during October-December (Figure 3).

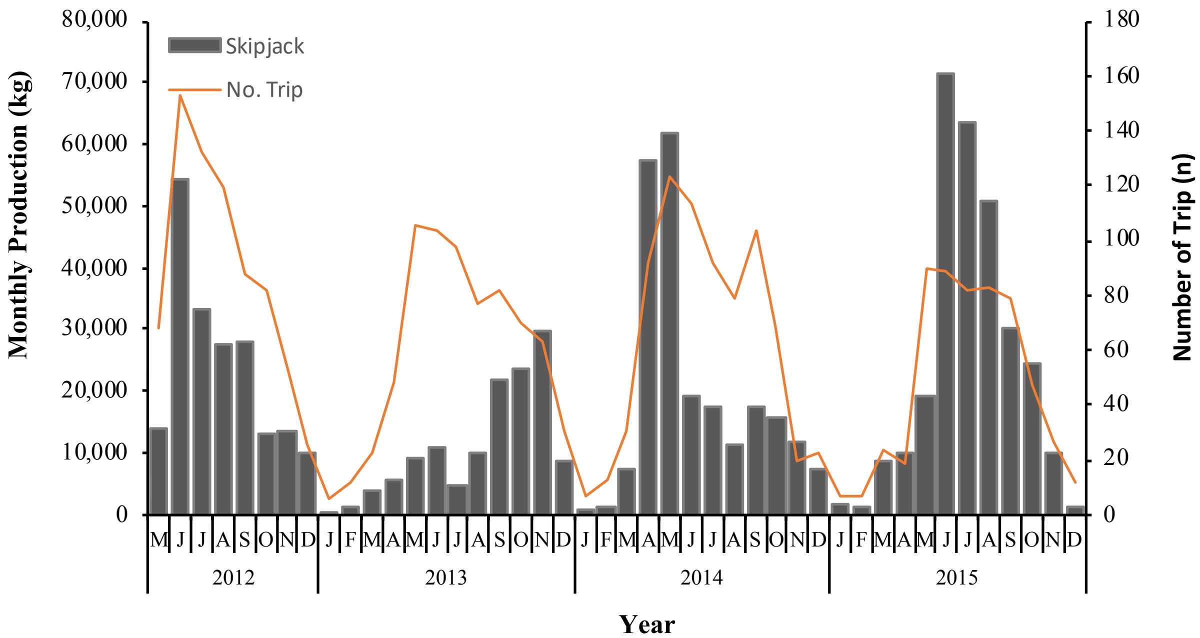

Figure 2. Monthly total production and number of trips of skipjack from hand-line fisheries based in Pacitan.

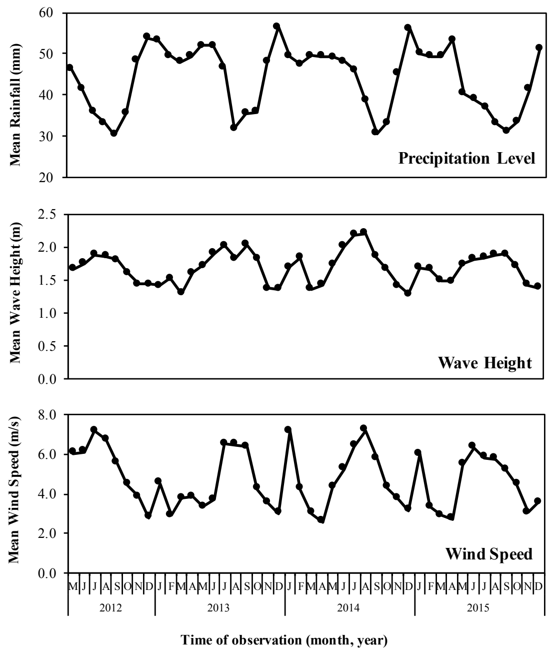

Figure 3. Mean value of environmental variables presented in monthly time series data.

Based on Pearson's correlation coefficient, moderate correlation showed between wind speed and precipitation level, r=0.44, n=2.758 and between wind speed and wave height, r=0.41, n=2.758. While weak correlation showed between precipitation level and wave height r=0.17, n=2.758. A scatterplot summarizes the results (Figure 4). Overall, there was no strong correlation among all environmental variables, thus they can be incorporated into the model.

Skipjack tuna fishing season

The best model options as determined according to AIC value were summarized in Table 1. Analysis of variance result showed that among all covariates, Year, Month, WindSpeed and Fastled have significant effect to the CPUE (P<0.05), while both precipitation level and wave height were not improving the AIC value and considered not significant, P>0.05 (Table 2). Thus, those variables removed from the final model. Model number 8 was listed as the final model because it has the lowest AIC value (24546.53) and highest Pseudo-R^2 (0.0721) compared to others.

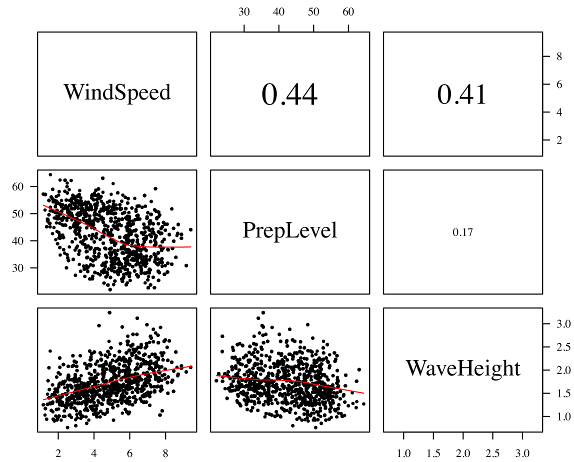

Figure 4. Pearson's correlation coefficient between wind speed, precipitation level and wave height.

Based on the final model, the fishing season of hand line skipjack tuna fishery in Pacitan, East Jawa take place all year around. Reached its peak in April and November and recorded the lowest in February, June and October. Stable season occurred during July-September (Figure 5). The quantile-quantile (QQ) residuals diagnostic plot given in Figure 6 (middle panel) showed that the residual skewed a little on the left-hand side because some predicted values obtained from the model corresponding to the zero-catch observations became positive.

Table 1. Summary of indicators as calculated using eight model scenarios, from the highest to the lowest deviance.

No.	Model Scenario	Deviance	AIC	Pseudo-R^2
1	CPUE~1	20249.84	24818.48	4.44E-16
2	CPUE~PrepLevel	20226.67	24816.10	0.0008
3	CPUE~PrepLevel+Year	19348.91	24653.76	0.0431
4	CPUE~PrepLevel+Year+Month	18836.00	24575.13	0.0647
5	CPUE~PrepLevel+Year+Month+WindSpeed	18711.68	24552.48	0.0706
6	CPUE~PrepLevel+Year+Month+WindSpeed+Fastled	18679.28	24548.04	0.0718
7	CPUE~PrepLevel+Year+Month+WindSpeed+Fastled+WaveHeight	18674.75	24549.14	0.0717
8	CPUE~Year+Month+WindSpeed+Fastled	18681.73	24546.53	0.0721

Table 2. Analysis of deviance table for full model (model 7).

	Df	Deviance	Resid. Df	Resid. Dev	F	Pr(>F)	Significance
NULL			2757	20249.84			
PrepLevel	1	23.1646	2756	20226.67	3.296	0.0696	
Year	3	877.7655	2753	19348.91	41.632	0.0000	***
Month	11	512.9111	2742	18836.00	6.635	0.0000	***
WindSpeed	1	124.3228	2741	18711.68	17.690	0.0000	***
Fastled	1	32.3949	2740	18679.28	4.609	0.0319	*
WaveHeight	1	4.5314	2739	18674.75	0.645	0.4221	

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

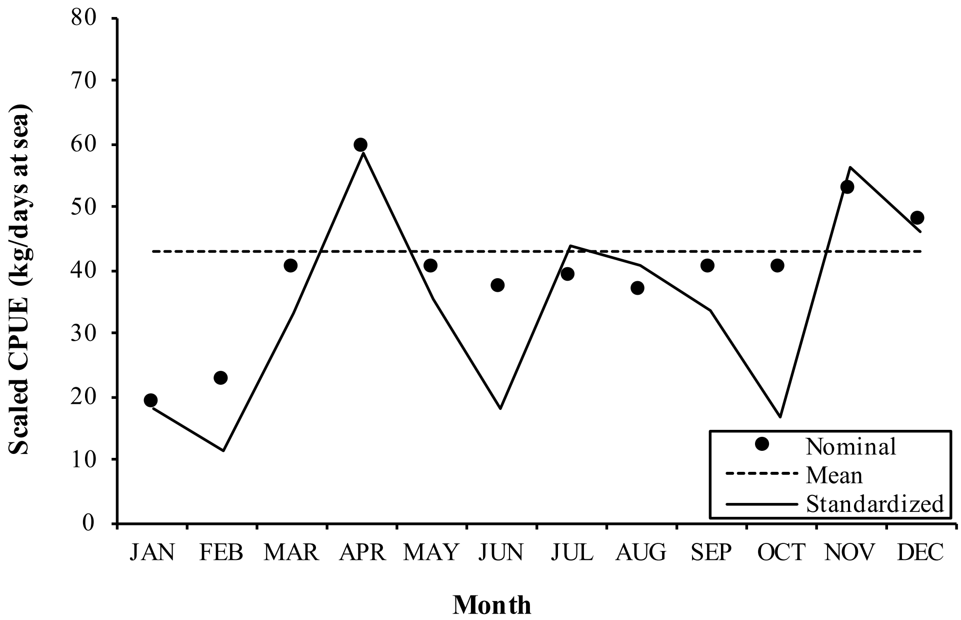

Figure 5. Monthly trends of CPUE obtained from Tweedie model as indicator of hand line skipjack tuna fishing season (Remark: Grey area is standard error)

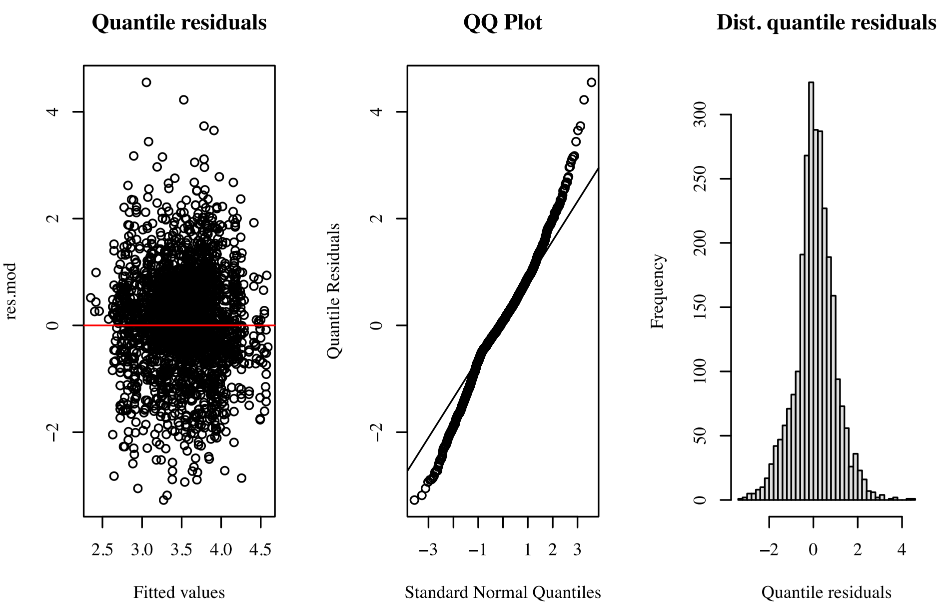

Figure 6. Quantile residuals, quantile-quantile and distribution of quantile residual diagnostic plot for skipjack tuna derived from GLM model using tweedie distribution.

b. Discussion

Fishing season always associated with abundance of fish caught during particular period (usually month). Previous studies suggested that effort is the main factor on determining the abundance of fishes. That is why most calculation of fishing season uses CPUE as basis analysis. Since the rapid development of remote sensing technology, more and more environmental aspect known to have influenced the catch of fish.

Sea surface temperature and chlorophyll-a are influential factors in skipjack distribution and abundance (Angraeni et al., 2014; Fraile et al., 2010; Amri, 2008). However, according to Simbolon and Limbong (2012) they did not contribute significantly to the volume of catch but rather to the distribution. The quantity of catch is likely driven by the number of efforts. While the number of efforts is driven by the surrounding environmental factors, especially in small-scale fisheries, which use less than 24 m length of boat.

Wave height and rainfall intensity did not affect the fishermen to go fishing. This is due to the range of wave height was still at the threshold of moderate, i.e. 1.25-2.50 m, whereas the rainfall intensity classified within the categories below normal, i.e. 1702-2303 mm (BMKG, 2016). The insignificancy of both wave height and rainfall were merely because the values were not strong enough to influence the fishing behavior, instead of the endurance from fishermen in respond to weather conditions. Stronger wind speed during June-August was caused by low sea surface temperature around the area, it usually followed by high concentration of chlorophyll-a which marked an upwelling (Ratnawati et al., 2016). Based on Beaufort scale, the range of wind speed during the observation categorized as light breeze (1.6-3.3 m/s) to moderate breeze (5.5-7.9 m/s) which is still suitable for fishing. However, some fishers may experience difficulties during operational when the wind speed exceed 7 m/s (January-March) because the boat usually narrow in width (± 2.5). surface wind speed is affecting the CPUE in negative direction, when surface wind speed increase, the CPUE is likely to decrease (Figure 7). Because it can seriously limited fishing operations and hamper the catchability of skipjack tuna by surface gears, especially purse seine (Evans et al., 1981). Previous study from Lasker (1975) found that increased wind speed can disrupt the stability of the mixed layer, therefore food aggregations will be scattered which affect survival of larvae or other organisms associated.

Many of small-scale hand line fishermen based in Pacitan originated from Kalimantan, Sulawesi and Nusa Tenggara Timur (Purwasih, 2016). They commonly known as “andon” or migrant fishers, which seasonally fishing outside their local area (southern part of Jawa and Nusa Tenggara) within a particular period of time (West et al., 2012). Since most of them are Muslim, some of them usually take time break before and after Ied Mubarak to visit their relatives at home. Hence, it might explain how FastIed variable is significantly affected the CPUE of skipjack tuna in the model ($P<0.05$).

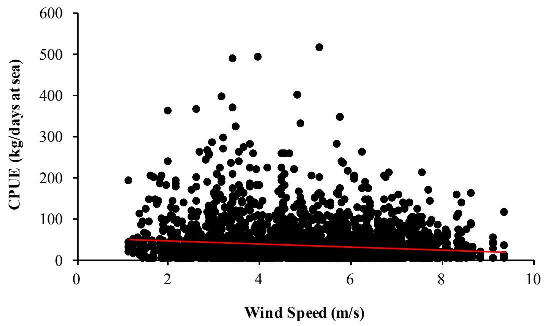

Figure 7. Relationship between CPUE of skipjack and wind speed variables. Red line is negative correlation trend.

The fishing season trend might be different among landing port location. For example, between Prigi and Pacitan, which both just 73 km apart and probably share the fishing ground, showed quite different trend. Setiyawan *et al.* (2013) reported that the skipjack fishing season in Prigi started in June and reach its peak in September, while in Pacitan June considered as low season, and the peak season in April and November. Perhaps more non-environmental related factors involved aside from this study, such as the deployment time of migrant fishers, overlapping with other seasonal high valued fish (cutlass fish) and the availability of FADs could be another driving force.

Accuracy of fishing season can assist managers to make any management measures in the future, such as open and close season. Even though skipjack tuna stock is not in the threatened condition, but the reported decreasing catch in recent years should be an early warning for this fishery (IOTC, 2016). By knowing the seasonal catch rate of skipjack, the effectiveness of fishing operations can be improved, so that the operational cost can be suppressed.

4. CONCLUSION

Small-scale hand line skipjack tuna fishing season start from March, reached its peak in April and October. The low season is Februari, June and September. Local weather (WindSpeed) and religious affair (FastIed) significantly affected the fishing behavior thus lead to dynamics of CPUE obtained.

5. ACKNOWLEDGEMENT

The authors would like to thank Vica Kristiana and Pradewa Yunian Griwandi for their contribution in collecting data throughout the years. This research is funded by DIPA APBN 2012-2015 for Research Institute for Tuna Fisheries (RITF). Revisit and reanalysis data, including its correlation with sea-air variables, has been conducted during 2016-2017. Gratefully thanks to Armyanda Tussadiah and Tonny Adam Theoyana (Marine & Coastal Data Laboratory, Marine Research Center, Jakarta) for all efforts extracting sea-air time series data.

6. REFERENCES

Adam, M.S., Sinan, H., Jauharee, A.R., Ziyad, A., Ahusan, M. 2012. Maldives national report submitted to the Indian Ocean Tuna Commission scientific committee 2012. IOTC-2012-SC15-NR17. 18 pp.

Akaike, H. 1974. A new look at the statistical identification model. IEEE Transactions on Automatic Control. 19, 716-723.

Amri, K. 2008. Analisis hubungan kondisi oseanografi dengan fluktuasi hasil tangkapan ikan pelagis di Selat Sunda. Jurnal Penelitian Perikanan Indonesia. 14(1), 51-61.

Angraeni, Rezkyanti, N.I., Safruddin., Zainuddin, M. 2014. Analisis spasial dan temporal hasil tangkapan ikan cakalang (*Katsuwonus pelamis*) dan *thermal front* pada musim peralihan di Perairan Teluk Bone. Jurnal IPTEKS PSP. 1(1), 20-27

Badan Meteorologi Klimatologi dan Geofisika (BMKG). 2016. Prakiraan musim hujan tahun 2016/2017 provinsi Jawa Timur. 42 pp. URL www.bmkg.go.id

Candy, S. G. 2004. Modelling catch and effort data using generalised linear models, the Tweedie distribution, random vessel effects and random stratum-by-year effects. Commission for the Conservation of Antarctic Marine Living Resources Science. 11, 59- 80.

Claus, S., De Hauwere, N., Vanhoorne, B., Souza Dias, F., Oset García, P., Hernandez, F., Mees, J (Flanders Marine Institute). 2017. MarineRegions.org. Accessed at http://www.marineregions.org on 2017-01-19.

Dajan, A. 1998. Pengantar metode statistik jilid I. Lembaga Penelitian Pendidikan Penerangan Ekonomi Sosial (LP3ES). Jakarta. 424 pp.

Dueri, S., Faugeras, B., Maury, O. 2012. Modelling the skipjack tuna dynamics in the Indian Ocean with APECOSM-E – Part 2: Parameter estimation and sensitivity analysis. Ecological Modelling. 245, 55-64.

Evans, R.H., McLain, D.R., Bauer, R.A. 1981. Atlantic Skipjack Tuna: Influences of Mean Environmental Conditions on Their Vulnerability to Surface Fishing Gear. Marine Fisheries Review. 43(6), 1-11.

Fonteneau, A., Chassot, E., Bodin, N. 2013. Global spatio-temporal patterns in tropical tuna purse seine fisheries on drifting fish aggregating devices (DFADs): Taking a historical perspective to inform current challenges. Aquatic Living Resources. 26, 37-48.

Fraile, I., Murua, H., Goni, N., Caballero, A. 2010. Effects of environmental factors on catch rates of FAD-associated yellowfin (*Thunnus albacares*) and skipjack (*Katsuwonus pelamis*) tunas in the western Indian Ocean. Paper presented in IOTC 12th session of working party of tropical tuna, Seychelles 18-25 October 2010. IOTC-2010-WPTT-46. 22 pp.

Hariati, T. 2011. Komposisi hasil tangkapan, musim penangkapan, dan indeks kelimpahan ikan pelagis yang tertangkap pukat cincin mini di Perairan Kendari, Laut Banda. Jurnal Penelitian Perikanan Indonesia. 17(2), 139-146.

Indian Ocean Tuna Commission (IOTC). 2016. Report of the 18th Session of the IOTC Working Party on Tropical Tunas.

Seychelles, 5-10 November 2016. IOTC–2016–WPTT18–R[E]. 126 pp.

Irianto, H.E., Wudianto., Fahmi, Z., Setyadji, B., Satria, F., Sadiyah, L., Nugraha, B., Widodo, A.A. 2016. Indonesia national report to the scientific committee of Indian Ocean Tuna Commission, 2016. IOTC-2016-SC19-NR10. 26 pp.

Kekenusa, J.S., Paendong, M.S. 2016. Analisis penentuan musim penangkapan ikan cakalang (*Katsuwonus pelamis* L.) di Perairan Belang Minahasa Tenggara-Sulawesi Utara. Jurnal Ilmiah Sains. 16(2), 86-90.

Lasker, R. 1975. Field criteria for survival of anchovy between inshore chlorophyl maximum layers and successful first feeding. Fisheries Bulletin National Oceanic Atmospheric Administration – National Marine Fisheries Service, 73(3):453–62.

Merta, I.G.S., Prisantoso, B.I., Bahar, S. 2004. Musim penangkapan ikan pelagis after Musim penangkapan di Indonesia. BRPL – BRKP. Jakarta.

Minami, M., Lennert-Cody, C. E., Gao, W., Román-Verdesoto, M. 2007. Modeling shark bycatch: The zero-inflated negative binomial regression model with smoothing. Fisheries Research. 84, 210-221.

Nurdin, E., Nugraha. B. 2008. Penangkapan tuna dan cakalang dengan menggunakan alat tangkap pancing ulur (*hand line*) yang berbasis di pangkalan pendaratan ikan Pondokdadap Sendang Biru, Malang. BAWAL. 2(1), 25-31.

Pranowo, W.S., Kuswardani, A.R.T.D., Nugraha, B., Novianto, D., Muawanah, U., Prihatno, H., Yu, W. 2016. Ocean-Climate Interaction of South Eastern Indian Ocean for Tuna Fisheries & Its Socio-Economy Impacts. International Journal of Science and Research. 5(4), 1956-1961.

Pranowo, W.S. 2014. Fenomena di Laut Selatan Jawa Tersebut Kami Beri Nama “RATU”. Article in Rubrik Maritime Opinion, Indonesia Maritime Magazine. Ed. 44/IV/Jun-2014/ ISSN: 2087-8060, 44-45.

Pranowo, W.S., Phillips, H., Wijffels, S. 2005. Upwelling Event 2003 Along South Java Sea & The Sea of Lesser Sunda Islands. Jurnal Segara. 1 (3), 116-123.

Purwasih, J.D., Wibowo, B.A., Triarso, I. 2016. analisis perbandingan pendapatan nelayan pukat cincin (*purse seine*) dan pancing tonda (*troll line*) di PPP Tamperan Pacitan, Jawa Timur. Journal of Fisheries Resources Utilization Management and Technology. 5(1), 37-46.

QGIS Development Team, 2009. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.osgeo.org

Ratnawati, H.I., Hidayat, R., Bey, A., June, T. 2016. Upwelling di Laut Banda dan Pesisir Selatan Jawa serta Hubungannya dengan ENSO dan IOD. Omni-Akuatika. 12 (3), 119-130

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Setiyawan, A., Haryuni, S.T., Wijopriono. 2013. Perkembangan hasil tangkapan per upaya dan pola musim penangkapan ikan cakalang (*Katsuwonus pelamis*) di Perairan Prigi, Provinsi Jawa Timur. Depik. 2(2), 76-81.

Simbolon, D., Limbong, M. 2012. Exploration of skipjack fishing ground through sea surface temperature and catches composition analyzes in Palabuhanratu Bay Waters. Journal of Coastal Development. 15(2), 225-233.

Spiegel, M. R. 1961. Theory and Problems of Statistics. Schaum Publ. Co., New York. 359 pp.

Tilik, M., Budiman, J., Wenno, J. 2014. Analisis musim penangkapan ikan cakalang di Perairan Kepala Burung, Papua. Jurnal Ilmu dan Teknologi Perikanan Tangkap I (Edisi Khusus). pp. 31-37

Tweedie, M. C. K. 1984. An index which distinguishes between some important exponential families. Statistics: Applications and New Directions.

Proceedings of the Indian Statistical Institute Golden Jubilee International Conference (Eds. J. K. Ghosh and J. Roy). pp. 579-604. Calcutta: Indian Statistical Institute.

Utamy, R.M., Purba, N.P., Pranowo, W.S., Suherman, H. 2015. The Pattern of South Equatorial Current and Primary Productivity in South Java Seas. International Proceedings of Chemical, Biological and Environmental Engineering. 90(2015), doi: 10.7763/IPCBEE. 2015. V90. 24. p.152-156.

West, R.J., Palma-Robes, M.A., Satria, F., Wudianto, Purwanto, Sadiyah, L., Prasetyo, A.P., Faizah, R., Setyanto, A. 2012. The Control and Management of Illegal, Unreported and Unregulated (IUU) Fishing in Fisheries Management Area 573. Report prepared for ACIAR Project FIS/2006/142, Developing new assessment and policy frameworks for Indonesia's marine fisheries, including the control and management of Illegal, Unregulated and Unreported (IUU) Fishing. Australian National Centre for Ocean Resources and Security (ANCORS), University of Wollongong, Australia. 56 pp.

Zulkasyni. 2014. Analisis musim penangkapan ikan cakalang di Perairan Bengkulu. Jurnal Agroqua. 12(2), 79-86