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THE EFFECT OF DEPTH OF HOOKS, SET AND SOAK TIME TO THE CATCH PER UNIT OF EFFORT OF TUNA IN THE EASTERN INDIAN OCEAN

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ABSTRACT

Yellowfin (*Thunnus albacares*) and bigeye (*T. obesus*) tuna have been intensively exploited by longline fleets since 1980's, however, a large proportion of zero catch per set of target species still accurred. Zero catch data contributed significantly to the low catch per unit of effort (CPUE) compared to other countries at the same fishing area. Therefore, understanding the factors contributed to the CPUE of tuna is essential, in order to improve longline fishing efficiency. A total of 2.115 set-by-set data were obtained from Indonesian Scientific Observer Program. The onboard observations were carried out at commercial tuna longline operated in Eastern Indian Ocean from August 2005 to December 2014. Several analytical approaches were conducted in this paper. First, General Linear Model (GLM) was applied in order to model the relationship between CPUE with all the variables involved. Second, boxplot diagram, polynomial and linear regression were applied to fit the relationship between CPUE with set time, soak time and depth (represented by hook position) respectively. The result showed that, there was no significant relationship between set time and CPUE of bigeye and yellowfin tuna. Soak time was positively related with CPUE of yellowfin and affect adversely on bigeye. Depth also have significant relationship with CPUE of tuna, where catch of yellowfin decreased linearly with hook depth, whereas catch of bigeye was performed the opposite. Improvement in tuna longline fishery in eastern Indian Ocean can be achieved through implementation of the specific soak time and hook depth for each target species, i.e. yellowfin and bigeye tuna.

Keywords: Yellowfin tuna; bigeye tuna; set time; soak time; hook depth; Indian Ocean

INTRODUCTION

Large highly migratory tuna, such as yellowfin (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) have long been the target fishery in Indian Ocean, mainly by the industrial longline vessels from Japan, Taiwan and Korea (Polacheck, 2006; Lee *et al.*, 2005). Estimation of total catch by all fleets in eastern Indian Ocean for yellowfin and bigeye tuna from Indian Ocean Tuna Commission (IOTC) was 94,699 mt and 37,724 mt, respectively (IOTC, 2014). Indonesia's contribution was up to 38% of total catch both yellowfin and bigeye in Indian Ocean, which mainly came from industrial longline fishery (IOTC, 2014). Even though it has become intensive target catch since 1980's, the latest stock assessment conducted by IOTC (2014) mentioned that both yellowfin and bigeye tuna stock were determined to be not overfished and were not subject to overfishing.

Long-lining was introduced to Indonesia by Japan in the 1930s, but not until the 1960s it has become commercial (Simorangkir, 1982; Proctor *et al.*, 2003). Currently, Indonesia has the largest number of fleet of commercial tuna long-line vessels in the Indian Ocean i.e. 1,256 registered vessels in 2011 (Irianto *et al.*, 2013). The large number of vessels were due to re-flagged (ownership shifting) of foreign vessels mainly from Taiwan and China (Sadiyah & Prisantoso, 2011). Large effort in the similar fishing ground usually resulted with low catch. The standardized CPUE of tuna Indonesian long-line fleets is lower compared to Japan or Korean fleets (Sadiyah *et al.*, 2011; Lee *et al.*, 2014; Ochi *et al.*, 2014). This inefficiency is

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showed by a large proportion of zero catch observations for target species that still occur in catch and effort data (Sadiyah *et al.*, 2011).

In order to improve long-line fishing efficiency, understanding the factors contributed to the catch of tuna is essential. Accurate set time, soak time and capture depths lead to significant improvements in fishery oceanographic relationships, vertical distribution, habitat preferences, and stock assessments (Boggs, 1992; Brill & Lutcavage, 2001). This work focused on the relationship among set time, soak time and hook depth to the catch of tuna, especially yellowfin and bigeye tuna in the eastern Indian Ocean.

MATERIALS AND METHODS

About 2,115 set-by-set data compiled from August 2005 to December 2014 were obtained from Indonesian Scientific Observer Program following commercial tuna longline operated in Eastern Indian Ocean and based in Muara Baru (Jakarta), Palabuhanratu (Jawa Barat), Cilacap (Jawa Tengah) and Benoa (Bali) (Fig. 1). The data set covered fishing date, location of deployment, number of hooks, number of hooks between float (HBF), set time, soak time and catch in number. Six data were excluded from analysis due to incomplete information on number of total hook or number hook between float. Catch and effort data were recorded as the number of fish per 100 of hooks recorded per set, respectively. The analysis in this chapter is only concerned with the two tuna species, namely yellowfin tuna (YFT) and bigeye tuna (BET).

In this study, a General Linear Model was used to investigate effect of set and soak time, and hook depth on the CPUE of tuna (defined as the number of fish per 100 hooks). This study limit only the interaction between CPUE and the operational factors related in longline fishery such as set time, soak time, number of hook between float and depth of hook.

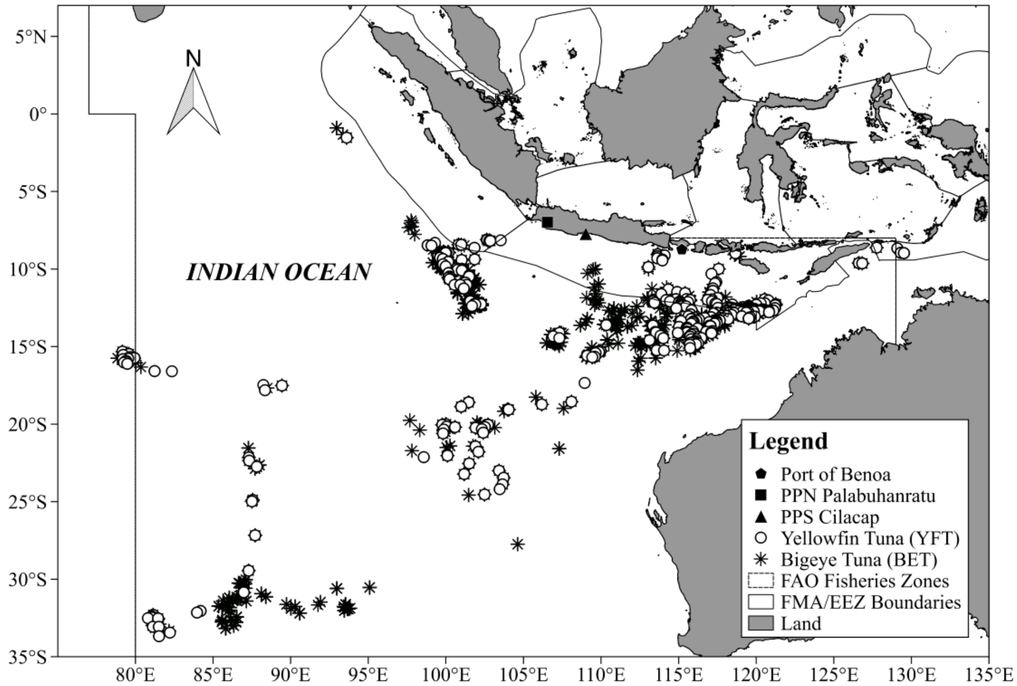

Figure 1. Geographic distribution location of Indonesian longline fishing activities showing the set deployment of both yellowfin (white dot) and bigeye (black asterisk) tuna.

Set time was divided into two categories i.e. day (00.00-18.00) and night (18.00-24.00). All time recorded was in GMT+8.The soak time is considered as the time elapsed between the start of set and the start of hauling of the fleet. A constant rate of longline retrieval was assumed throughout each operation. Soak time is divided into one-hour interval and converted into decimal. For example, soak time is defined to 5h if it was between 4.5h and 5.5h. For analysis, soak time is categorized into four categorical variables, namely A=6-8 hours, B=8-10 hours, C=10-12 hours, D=12-14 hours, E=14-16 hours and F=16-18 hours. Depth of hooks is considered as the position of hook between float (HBF), the higher the hook position number the deeper the hook (Fig. 2). There are 14 HBF configurations used by Indonesian long-liners, and for the analysis it is divided into four categorical variables (1=5-9; 2=10-12; 3=13-14; 4=15-21) according to Nishida & Wang (2006). The GLM model was presented below:

$$Log(CPUE + c) = \mu + Set + Soak + HBF + \varepsilon$$

where,

CPUE = nominal CPUE of tuna (No. fish/100 hooks),
c = constant value (i.e. 10% of the average nominal CPUE)
μ = intercept,
Set = effect of set time,
Soak = effect of soak time,
HBF = effect of HBF,
ε = the error term (normally distributed), n=1,2,3.

One-way analysis of variance (ANOVA) (a = 0.05) was used to find the any significance among parameters toward CPUE.

Boxplot diagram was used in order to further investigate the relationship of set time against CPUE. Polynomial regression ($y = ax^2 + bx + c$) was used to describe the relationship between soak time and CPUE, where *a* and *b* are the coefficients, *c* is an intercept, *x* is the soak time, *y* is CPUE. Then the optimum soak time of tuna long-line fishing gear can be estimated afterwards. Linear regression ($y = ax + b$) was used to describe the relationship between depth (represented by hook position) and CPUE, where *a* is a coefficient, *b* is an intercept, *x* is the hook position, y is CPUE. One-way ANOVA (a = 0.05) was used to find any correlation between hook depth and nominal catch of tuna. All statistical data were analyzed using R software version 3.1.3 (R Core Team, 2016). The map was drawn using open source mapping software QGIS version 2.8.1.

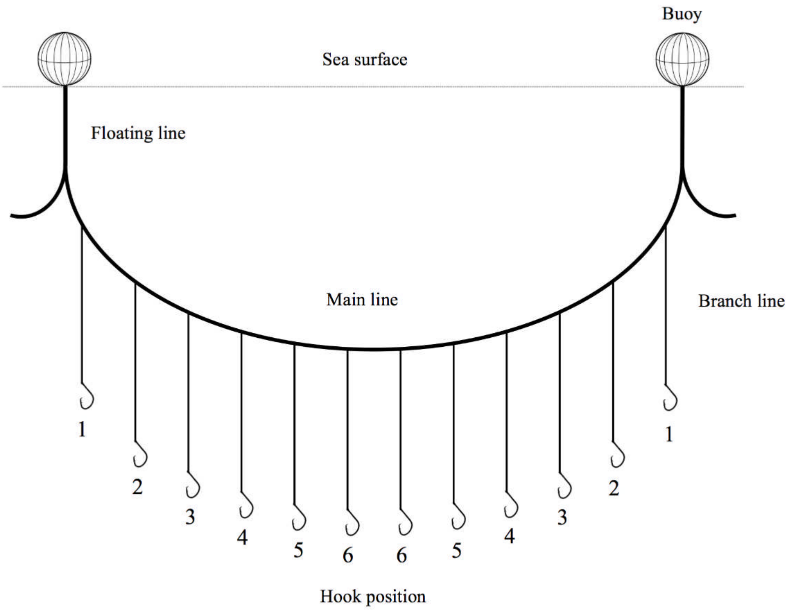

Figure 2. The configuration of long-line fishing gear (HBF=12).

RESULTS AND DISCUSSION

Results

During all 87 trips from 2005 to 2014, the time of commencement and completion of set and the haul of the two ends of the gear were noted. Most of sets were done at daytime (96% for yellowfin and 97% for bigeye), between 06.00-12.00 am. Soak time noted in this study ranged from 5-24 hours. Soak time data less than 6 hours and more than 18 hours were omitted from the analysis, due to lack of representative samples and might cause bias. GLM model for both BET and YFT shows that, the nominal CPUE was significantly affected by soak time ($P<0.05$) and HBF ($P<0.01$) (Table 1, Table 2). AIC value was-70.249 and -301.38, respectively for BET and YFT. The set time was unlikely affected CPUE on both models.

Boxplot diagram shows that there was no difference between mean values of CPUE against set time (Figure 3). The relationships between CPUE of BET and YFT against soak time are indicated in Figure

4 and can be described in quadratic regression as follows:

For yellowfin tuna: $y = -0.003x^2 + 0.081x + -0.273$,
$R^2 = 0.5649$
For bigeye tuna: $y = 0.009x^2 + -0.227x + 1.616$,
$R^2 = 0.6831$

Obviously soak time is affected adversely to the CPUE of YFT and BET. CPUEs of YFT increased simultaneously with the duration of soak time, and then gradually decreased after reached its peak. As for BET, the longer soak time produced lower CPUE even though from 12 hours onward it started to increase. From both quadratic equations, the CPUE of YFT reached its peak at soak time around 12 hours, while for BET was around 6 hours. However, it is noted that the increase of CPUEs did not positively related with the increasing of soak time, instead, it decline for YFT, whereas for BET it is the opposite.

The example of HBF 12 and 18 were taken to configure the relationship of hook depth (represented by hook position number) with the catch of both BET and YFT. The result shows that catch of BET increased linearly with hook depth, whereas catch of YFT was performed adversely (Fig. 5).

Table 1. Analysis of deviance and summary table of GLM model for BET.

	Df	Deviance	Resid. Df	Resid. Dev	Pr(>Chi)	
NULL			1480	87.235		
catSet	1	0.1921	1479	87.043	0.06276	.
catSoak	3	1.2493	1476	85.794	5.07E-05	***
catHBF	3	4.0978	1473	81.696	6.28E-16	***

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

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-1.72601	0.16434	-10.503	< 2e-16	***
catSetNight	-0.07468	0.22933	-0.326	0.74473	
catSoakB	0.05735	0.04796	1.196	0.231974	
catSoakC	0.23204	0.09956	2.331	0.019901	*
catSoakD	0.29442	0.17957	1.64	0.1013	
catHBF2	0.26371	0.16273	1.621	0.105325	
catHBF3	0.58685	0.16494	3.558	0.000386	***
catHBF4	0.68122	0.1627	4.187	2.99E-05	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
AIC=-70,249

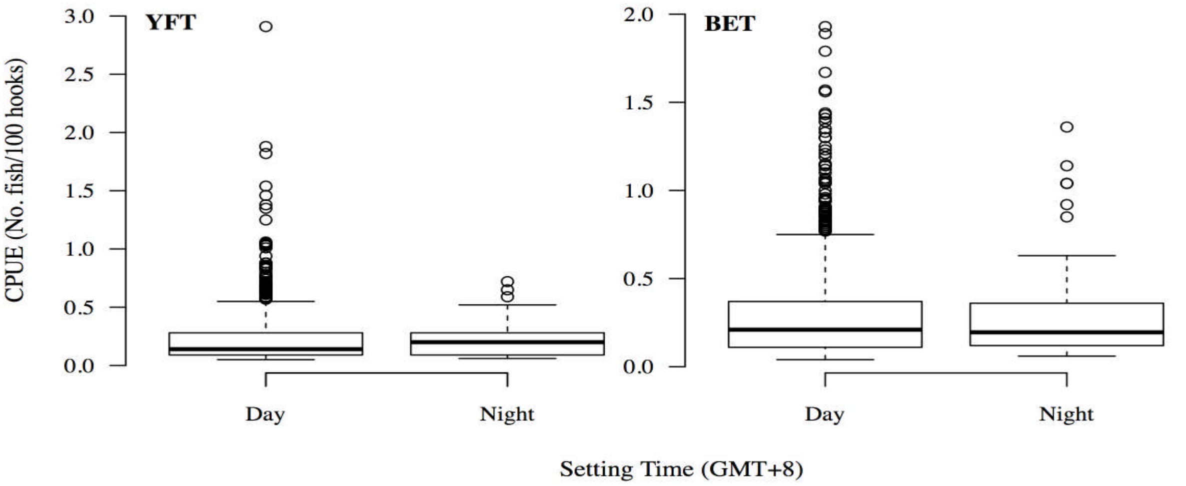

Figure 3. Boxplot of mean CPUE of both yellowfin (YFT) and bigeye tuna (BET) against set time (day and night).

Table 2. Analysis of deviance and summary table of GLM model for YFT.

	Df	Deviance Resid.	Df	Resid. Dev	Pr(>Chi)	
NULL			742	30.805		
catSet	1	0.0473	741	30.757	0.2677	
catSoak	3	1.2005	738	29.557	7.81E-07	***
catHBF	3	1.2538	735	28.303	3.99E-07	***

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

	Estimate	Std. Error	t value	Pr(>|t|)	
(Intercept)	-1.45528	0.15251	-9.542	< 2e-16	***
catSetNight	-0.07065	0.17459	-0.405	0.6858	
catSoakB	0.33013	0.14275	2.313	0.021	*
catSoakC	0.07121	0.30405	0.234	0.8149	
catSoakD	0.50537	0.26813	1.885	0.0599	.
catHBF2	-0.35714	0.07732	-4.619	4.56E-06	***
catHBF3	-0.74828	0.18824	-3.975	7.73E-05	***
catHBF4	-0.59265	0.14669	-4.04	5.90E-05	***

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
AIC=-301.380

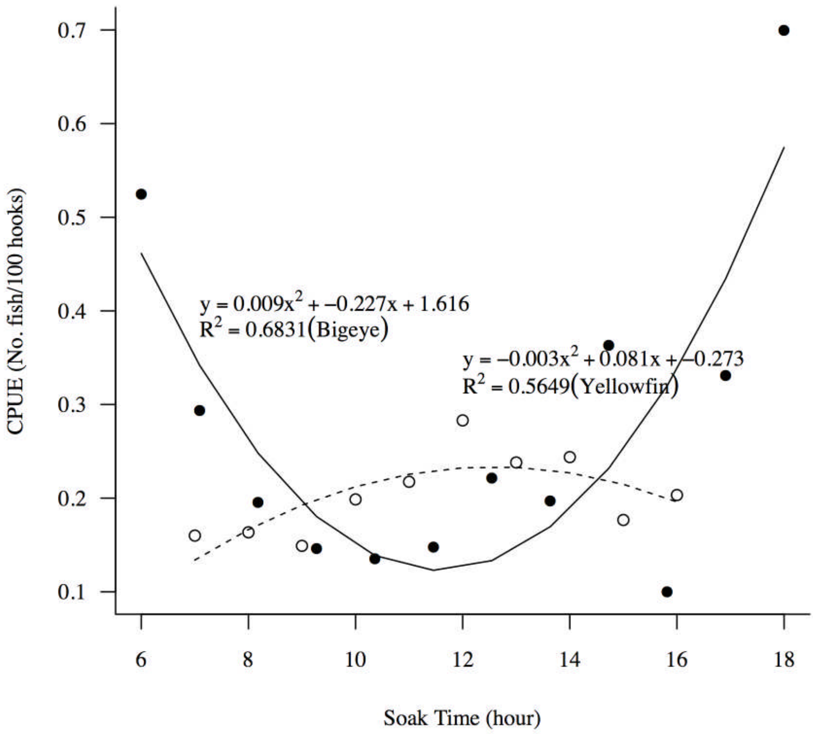

Figure 4. The quadratic regression curves between CPUE of both yellowfin (YFT, white dot, straight line) and bigeye tuna (BET, black dot, dashed line) and soak time.

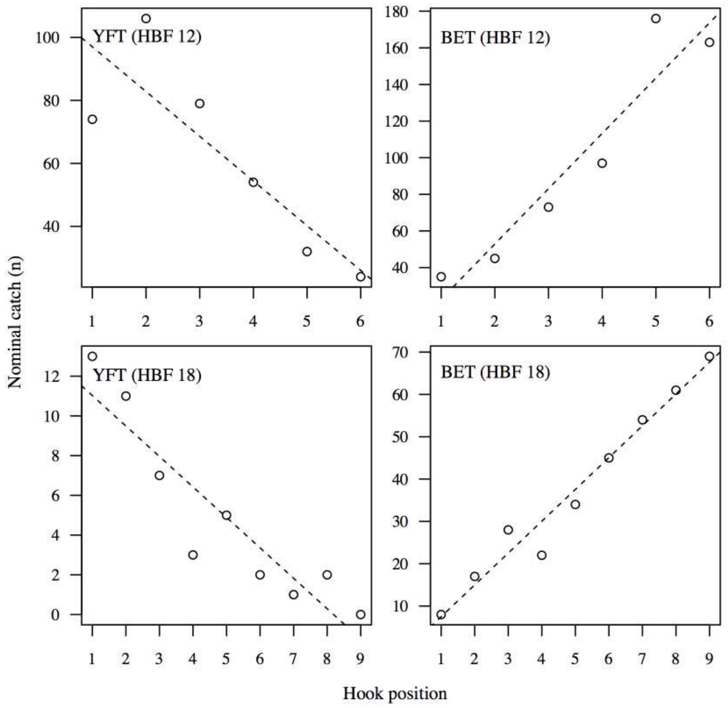

Figure 5. The linear regression lines between nominal catch of both yellowfin (YFT) and bigeye tuna (BET) and hook depth (HBF 12 and HBF 18).

Discussion

Set time did not affect the CPUE for both YFT and BET. This could be understood as an adaptation of fishermen to the behavior of tuna by adjusting the longline set. Several studies revealed that both yellowfin and bigeye tuna mostly occupy shallower water at night and deeper water layer at day (Weng *et al.*, 2009; Schaefer *et al.*, 2011; Evans *et al*., 2008; Brill *et al*., 2005). There is also a common knowledge among Indonesian fisheries, at full moon set is started at dawn, while at new moon set is started at early morning (Barata *et al*., 2011). This knowledge is combined with adjusting the number of HBF during set resulted in higher probability of catch for both YFT and BET either day or night. The most commonly used HBF configuration was 5, 12, 18 (Irianto *et al*., 2013).

Soak time contributed significantly to CPUE of tuna, although it vary between YFT and BET. The result is similar with the study of Chen *et al.* (2012) in western Indian Sea, at least for YFT, while for BET it has been totally different projection. This may be due to several causes, i.e. the number of samples used for their analysis was smaller (BET=69, YFT=31) compared to this study (BET=6,191 and YFT=2,568), and the use of just one HBF configuration might cause bias. The optimum soak time for YFT was around 12 hours, similar with Chen *et al.* (2012), while for BET was around 6 hours. The reason why the CPUE of YFT was decreased along with the soak time was probably due to bait deteriorating during soak (Chen *et al.*, 2012), and fish that survived being hooked and the present of scavengers which can easily eat or remove hooked animals (Ward *et al*., 2003). This model is also applied on most shark and billfish (Ward *et al.*, 2003). As for the model for BET in this study was projected differently compared to Chen *et al.* (2012). The reason was still unclear, but the possible reason might be lied on the set time and the use of deep longline configuration (HBF >10) by most Indonesian fleets, since 1983 shifting target fishery from YFT to BET (Sadiyah *et al*., 2011). The use of deep longline configuration combined with night set will likely come up with a result in more BET caught in first 6 hours of deployment, while set at day will be resulted in more BET caught after 12 hours of deployment.

Aside of operational factors used in this analysis, Sadiyah *et al.* (2012) reported that year, area and bait factors significantly influenced the nominal CPUEs of tuna known as technological creep. However, this study did not discuss about those factors and mainly focused on operational aspects related to the CPUE. Most of YFT was caught at lower number of hook position, because it spent more of the time inhibit shallower depth layer (Dagorn *et al.*, 2006; Cayré, 1991; Bigelow *et al.*, 1999), while BET has been mostly caught at higher number of hook position because even it has the same vertical migration behavior with YFT. This demonstrated distinct diurnal behavior in depth and water temperature preferences, with deeper, cooler waters frequented during the day and shallower, warmer waters frequented at night (Musyl *et al.*, 2003; Evans *et al.*, 2008).

CONCLUSION

Set time doesn't have any correlation with CPUE on both tuna, while soak time was positively related with CPUE of yellowfin and affect adversely on bigeye. Depth also have significant relationship with CPUE of tuna, where catch of yellowfin decreased linearly with hook depth, whereas catch of bigeye was performed the opposite. Improvement in tuna longline fishery in eastern Indian Ocean can be achieved through implementation of the specific soak time and hook depth for each target species, i.e. yellowfin and bigeye tuna.

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REFERENCES

Barata, A., Bahtiar, A. & Hartaty, H. (2011).The Influence of different bait and set time of tuna longline on the tuna catch in Indian Ocean(in Indonesian)*. J. Lit. Perikanan. Ind*. Research Centre for Capture Fisheries. 17 (2), 133-138.

Bigelow, K.A., Hampton, J., & Miyabe, N. (1999). Effective longline effort within the yellowfin habitat and standardized CPUE. *Working paper on standing committee on tuna and billfish, 16-23 June 1999, Tahiti*. 10 p.

Boggs, C.H. (1992). Depth, capture time, and hooked longevity of longline- caught pelagic fish: timing bites of fish with chips. *Fish. Bull.* 90, 642–658.

Brill, R.W., Bigelow, K.A., Musyl, M.K., Fritsches, K.A., & Warrant, E. J. (2005). Bigeye tuna (*Thunnusobesus*) behavior and physiology and their relevance to stock assessments and fishery biology. *Col. Vol. Sci. Pap. ICCAT*. 57 (2), 142-161.

Brill, R.W., & Lutcavage, M.E. (2001). Understanding environmental influences on movements and depth distributions of tunas and billfishes can significantly improve population assessments. *In*: Sedberry, G. (Ed.): Island in the Stream: Oceanography and Fisheries of the Charleston Bump. Proceedings of the American Fisheries Society Symposium 25. Bethesda, MD.

Cayré, P. (1991). Behaviour of yellowfin tuna *(Thunnusalbacares)* and skipjack tuna *(Katsuwonuspelamis)* around fish aggregating devices (FADs) in the Comoros Islands as determined by ultrasonic tagging. *Aquat. Living Resour*. 4: 1-12. DOI: http://dx.doi.org/10.1051/alr/1991000.

Chen, W., Song L., Li J., Xu W., & Li, D. (2012). Optimum soak time of tuna longline gear in the Indian Ocean. *Paper presented on Fourteenth Working Party on Tropical Tunas, Mauritius, 24–29 October 2012.IOTC–2012–WPTT14–11*. 13p.

Dagorn, L., Holland, K.N., Hallier, J.P., Taquet, M., Moreno, G., Sancho, G., Itano, D.G., Aumeeruddy, R., Girard, C., Million., & Fonteneau, J. A. (2006). Deep diving behavior observed in yellowfin tuna (*Thunnusalbacares*). *Aquat. Living Resour*. 19, 85–88. DOI: 10.1051/alr:2006008.

Evans, K., Langley, A., Clear, N.P., Williams, P., Patterson, T., Sibert, J., Hampton, J., & Gunn, J.S. (2008). Behaviour and habitat preferences of bigeye tuna (*Thunnusobesus*) and their influence on longline fishery catches in the western Coral Sea. *Can. J. Fish.Aquat. Sci*. 65, 2427–2443. DOI:10.1139/F08-148.

Indian Ocean Tuna Commission (IOTC). (2014). Report of the Sixteenth Session of the IOTC Working Party on Tropical Tunas. Bali, Indonesia, 15–19 November 2014. *IOTC–2014–WPTT16–R[E]:* 104p.

Irianto, H.E., Wudianto., Satria, F. & Nugraha, B. (2013). Tropical tuna fisheries in the Indian Ocean of Indonesia. *Paper presented on fifteen Working Party on Tropical Tunas, Spain, 23–28 October 2013*.

Lee, P.F., Chen, I.C., & Tzeng, W.N. (2005). Spatial and temporal distribution patterns of bigeye tuna (*Thunnusobesus*) in the Indian Ocean. *Zool Stud*. 44 (2), 260-270.

Lee, S.I., Kim, Z.G., Lee, M.K., Ku, J.E., Park, W.P., & Lee, D.W. (2014). CPUE standardization of bigeye tuna caught by Korean tuna longline fishery in the Indian Ocean. *Paper presented on Sixteenth Session of the IOTC Working Party on Tropical Tunas. Bali, Indonesia, 15–19 November 2014.IOTC–2014–WPTT16–30*. 10 p.

Musyl, M.K., Brill, R.W., Boggs, C.H., Curran, D.S., Kazama, T.K., & Seki, M.P. (2003). Vertical movements of bigeye tuna (*Thunnusobesus*) associated with islands, buoys, and seamounts near the main Hawaiian Islands from archival tagging data. Fish. *Oceanogr*. 12(3): 152–169. DOI: 10.1046/j.1365-2419.2003.00229.x

Nishida, T., & Wang,S.P. (2006). Standardization of swordfish (*Xiphias gladius*) CPUEof the Japanese tuna longline fisheries in the Indian Ocean (1975-2004). *Paper presented in Fifth Session of the IOTC Working Party on Billfish, Colombo, Sri Lanka, 27-31 March 2006*. 10 p.

Ochi, D., Matsumoto, T., Satoh, K., & Okamoto, H. (2014). Japanese longline CPUE for bigeye tuna in the Indian Ocean standardized by GLM. *Paper presented on Sixteenth Session of the IOTC Working Party on Tropical Tunas. Bali, Indonesia, 15–19 November 2014. IOTC–2014–WPTT16–29.* 28 p.

Polacheck, T. (2006). Tuna longline catch rates in the Indian Ocean: Did industrial fishing result in a 90% rapid decline in the abundance of large predatory species? *Mar Policy* 30: 470–482. DOI:10.1016/j.marpol.2005.06.016.

Proctor, C. H., Merta, I.G.S., Sondita, M.F.A., Wahju, R.I., Davis, T.L.O., Gunn, J.S., & Andamari, R.(2003). A review of Indonesia's Indian Ocean tuna fisheries. ACIAR Country Status Report.

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/.

Sadiyah, L., & Prisantoso, B.I. (2011). Fishing strategy of the Indonesian tuna longliners in Indian Ocean. *Ind.Fish.Res.J.* Research Centre for Capture Fisheries. 17 (1), 29-35.

Sadiyah, L., Dowling, N., & Prisantoso, B.I. (2011). Changes in fishing pattern from surface to deep longline fishing by the Indonesian vessels operating in the Indian Ocean. *Ind.FishRes.J*. Research Centre for Capture Fisheries. 17 (2),87-99.

Sadiyah, L., Dowling, N., & Prisantoso, B.I. (2012). Developing recommendations for undertaking CPUE standardisation using observer program data. *Ind.FishRes.J*. Research Centre for Fisheries Management and Conservation.18 (1), 19-33.

Schaefer, K.M., Fuller, D.W., & Block, B.A. (2011). Movements, behavior, and habitat utilization of yellowfin tuna (*Thunnusalbacares*) in the Pacific Ocean off Baja California, Mexico, determined from archival tag data analyses, including unscented Kalman filtering. *Fish Res*. 112, 22–37. DOI:10.1016/j.fishres.2011.08.006.

Simorangkir, S. (1982). Tuna longline fishery in Indonesia. *In* Simorangkir, S. (Ed.):Indonesian fishery(in Indonesian). Bali, Indonesia, Bali Post.

Ward, P., Myers, R.A., & Blanchard, W. (2003). Fish lost at sea: the effect of soak time on pelagic longline catches. *Fish. Bull*. 102,179–195.

Weng, K.C., Stokesbury, M.J.W., Boustany, A.M., Seitz, A.C., Teo, S.L.H., Miller, S.K., & Block, B.A. (2009). Habitat and behaviour of yellowfin tuna *Thunnusalbacares* in the Gulf of Mexico determined using pop-up satellite archival tags. *J Fish Biol* 74: 1434–1449. DOI:10.1111/j.1095-8649.2009.02209.x.