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Optimum soak time of tuna longline gear in the Indian Ocean[1]

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Abstract: Based on the data collected in the tuna longline survey from September 2005 to December 2005 in the Indian Ocean, the calculation models of soak time for every branch line were built by two modes of hook retrieval in this study. The soak time of hook is divided into one hour interval for the quantity of hooks and the individuals of bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacores*), respectively. The respective catch rates (CPUEs) of bigeye tuna and yellowfin tuna in each hour interval were calculated. The results showed that (1) both CPUE of bigeye tuna and yellowfin tuna presented increasing at first and then decreasing trend along the increase of soak time; (2) the quadratic curves can be used to fit the relationships between soak time and the CPUEs of bigeye tuna, and yellowfin tuna; (3) the CPUEs of bigeye tuna and yellowfin tuna has been the highest when soak time were from 11.5 to 12.5h and from 10.5h to 11.5h, respectively. This study suggests that (1) the soak time of branch lines should last for about 10.5~12.5h in the tuna longline operation to improve fishing efficiency and reduce bycatch; (2) the soak time of the longline gear could be considered as the effective fishing effort and used to standardize CPUE.

Key words: bigeye tuna (*Thunnus obesus*); yellowfin tuna (*Thunnus albacores*); tuna longline; soak time; catch rate

It is well known that the CPUE of target species in longline fishery has been affected by technologies, biology and environmental variables (Sutterlin *et al.*,1982;

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Bjordal *et al*., 1988; Zhan, 1995). Therefore, the soak time of fishing gear will influence fishing efficiency and fishing mortality. In the previous studies, they found that no notable impact was made on CPUE, resulting from the increasing of soak time (Skud, 1978; Svein and Teresa, 1997). However, in the recent studies, the obvious relationship between CPUE and soak time has proposed. By GLM model, Carruthers *et al*. (2011) found that the CPUE of swordfish (*Xiphias gladius*) didn't increase with the minimum soak time (from the end of deployment to the start of retrieval), but a linear relationship exhibited between CPUE and maximum soak time (from the end of deployment to the end of retrieval). Thus, the minimum soak time should be shortened to reduce the bycatch mortality and meanwhile the CPUE of swordfish remains unaffected. Skud (1978) proved that the increasing level of total catch in the demersal longline declined with the soak time increasing. Other study has shown that shorter soak time contributed to the reduction of sea turtle bycatch (Vega and Licandeo, 2009) and the mortality of hooked fishes (Ogura *et al.*, 1980; Carruthers *et al.*, 2011). Vega and Licandeo (2009) pointed out the soak time influence the CPUEs of swordfish and blue shark (*Prionace glauca*) greatly in the swordfish longline fishery. So far, the relationship between the soak time of tuna longline fishing gear and the CPUEs of bigeye tuna and yellowfin tuna has been rarely studied(Sivasubramaniam, 1961). Based on the data collected in the tuna longline survey from September 2005 to December 2005 in the Indian Ocean, the calculation models of soak time for every branch line were built by two modes of hook retrieval in this study. We applied the calculation models of soak time to calculate and analyze the relationship between soak time and the CPUEs of bigeye tuna and yellowfin tuna. The optimum soak time of tuna longline fishing gear was determined. It will be beneficial to improve the fishing efficiency.

1 MATERIALS AND METHODS

1.1 Investigation duration, area and sites

The ocean-going longliner "Huayuanyu No.18" (overall length 26.12 m; gross tonnage 150 t) was used to conduct the survey. The hook depth and the sinking rate were measured by TDRs (TDR 2050, RBR Co., Ottawa, Canada). The survey was conducted from September 16, 2005 to December 12, 2005. The survey sites were shown in Fig. 1.

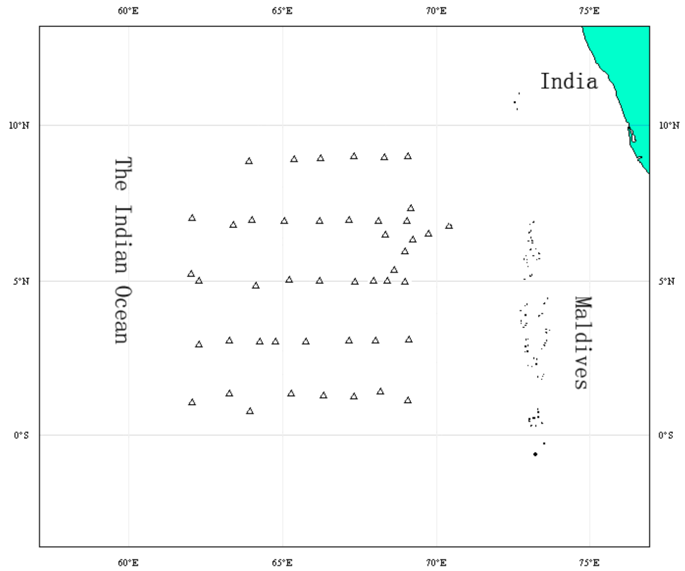

Fig.1 Area and sites of investigation

1.2 Fishing gear and fishing method

The longline used in this study consisted of 3.6 mm diameter monofilament main line, 360 mm diameter hard plastic float, 6 mm diameter nylon float line and two types of branch line ending in ring hook or circle hook. The lengths of main line and float line were 110 km and 25 m, respectively. For the branch line of the conventional and experimental gear, the first section was the 6 mm diameter polypropylene (1.5 m long), the second section was the 1.8 mm diameter nylon (14 m long), and the third section was the 1.2 mm stainless wire (0.5 m long). There were two parts in the first section, connected with a leaden barrel swivel. No swivel was used to connect the first and second sections, while a swivel used to connect the second and third sections. The third section was connected with the hook directly. The total length of the branch line of the conventional and experimental gear was about 16 m. The configuration of conventional and experimental fishing gear between two floats was shown in Fig. 2 and Fig. 3, respectively.

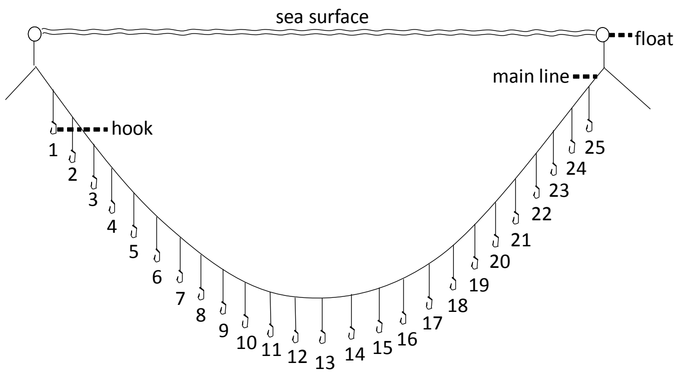

Fig.2 The configuration of fishing gear between two floats

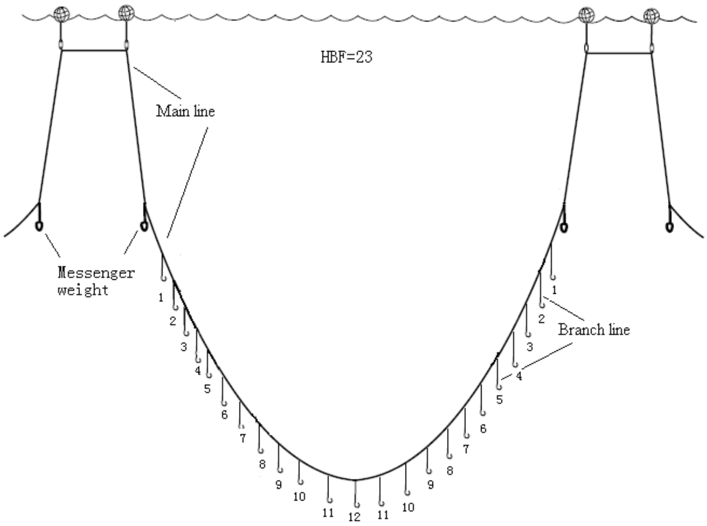

Fig.3 The configuration of experimental fishing gear between two floats

In general, the gear deployment occurred from 05:00 to 09:00 local time, lasted for about 4 hrs. The gear was retrieved between 15:30 and 21:00, lasting for 8 to 10 hrs. Sampling sites were selected in accordance with the traditional tuna fishing grounds of the Indian Ocean, but the actual sampling sites were slightly different from those that were planned due to logistical problems.

In operation, the vessel speed was about 4.30 m s^{-1} and line shooter speed was about 5.58 m s^{-1}. The time interval between deploying the fore and after branch lines was 8 s, 25 hooks deployed between two floats. In most cases, the fishing vessel used 100 circle hooks, 368 experimental hooks, and 200 to 1500 ring hooks per set. The total hooks per set ranged from 700 to 2200 hooks (Song *et al*., 2009). There were no significant differences between the conventional gears and experimental gears in the catch rates of bigeye tuna or yellowfin tuna. There were no significant differences in the catch rate of bigeye tuna or yellowfin tuna between the ring hooks and circle hooks. The data for conventional gears, experimental gears, ring hooks, and circle hooks can be combined to analyze (Song *et al*., 2008;2009).

When the experimental fishing gear was deployed, the first branch line close to floats was absent and the second one was replaced by messenger weight with different weight (1.5 kg and 2.5 kg in water), other parameters unchanged. The amount of the experimental hooks per type was 46, and all together 368 hooks were deployed.

During the investigation, the following operational data were also collected: deployment position and time, course and speed, line shooter speed, number of hooks, time of retrieving lines, code of hook with which a fish was caught, number of hooked bigeye tuna and yellowfin tuna per day, and hooked position of bigeye tuna and yellowfin tuna.

1.3 Data analysis

1.3.1 The soak time estimation

We assumed that T_{1s}^k and T_{1f}^k were starting and ending time of deploying longline gear at the *k*-th operation, respectively; T_{2s}^k and T_{2f}^k were starting and ending time of retrieval. There were M_k+1 floats (*i.e.* M_k sections). There were 25 hooks between two successive floats. T_3^k was assumed as the elapsing time from the end of deploying to the start of retrieval. The time interval of deploying two successive hooks was $\Delta t = 8s$. The time at which all branch lines between two successive floats were deployed was ΔT_d. Owing to the fixed line shooting speed of deployment, the time interval between two successive hooks (Δt) was used as the time unit to calculate the soak time of fishing gear in the process of deployment. Many factors affected the line retrieval speed, such as the distribution of catches among branch lines. The line retrieval speed was assumed to be constant during retrieval in this study. We assumed there were three parts of total soak time for each operation, and T_1^k, T_2^k, T_3^k indicated the soak time during deploying, retrieval, and the elapsing time from the end of deploying to the start of retrieval, respectively. Two models for retrieval were: (1) retrieval was started from the starting position of deploying; (2) retrieval was started from the end position of deploying. Based on these assumptions, the soak time of *j-th* hook in *i-th* float, and *k-th* operation was calculated as follows:

(1) Retrieval was started from the starting position of deploying

$$T_1^k = M_k(N+1)\Delta t - (i-1)\Delta T_d - j\Delta t \quad (1)$$

$$\Delta T_d = (N+1)\Delta t \quad (2)$$

$$T_2^k = [(N+1)(i-1)+j]\frac{T_{2f}^k - T_{2s}^k}{(N+1)M_k} \quad (3)$$

$$T_3^k = T_{2s}^k - T_{1f}^k \quad (4)$$

$$t_{i,j}^k = T_1^k + T_2^k + T_3^k \quad (5)$$

$$t_{i,j}^k = [(M_k - i + 1)(N+1) - j]\Delta t + [(N+1)(i-1)+j]\frac{T_{2f}^k - T_{2s}^k}{(N+1)M_k} + T_{2s}^k - T_{1f}^k \quad (6)$$

(2) Retrieval was started from the end position of deploying

$$T_2^{k\prime} = [(N+1)(M_k - i) + (N+1) - j]\frac{T_{2f}^k - T_{2s}^k}{(N+1)M_k} \quad (7)$$

$$t_{i,j}^{k}{}' = T_1^k + T_2^{k\prime} + T_3^k \quad (8)$$

$$t_{i,j}^{k}{}' = [(M_k - i + 1)(N+1) - j][\Delta t + \frac{T_{2f}^k - T_{2s}^k}{(N+1)M_k}] + T_{2s}^k - T_{1f}^k \quad (9)$$

Soak time of each hook when it was stable was computed. That is, the total soak time minus settling time of each hook. In this study, we assumed that the settling time of each hook (1~25) between two successive floats was constant in the successive floats at random, and was defined as $t_j^k (j = 1, 2, \cdots, 25)$. The settling time of each hook was measured by the TDR. We calculated the average settling time for each hook (1~25) between two successive floats in the investigation (Table 1). The soak time of each hook when it was stable was:

Retrieval was started from the start position of deploying:

$$T_{i,j}^k = t_{i,j}^k - t_j^k \quad (10)$$

Retrieval was started from the end position of deploying:

$$T_{i,j}^{k}{}' = t_{i,j}^{k}{}' - t_{j}^{k} \quad (11)$$

Tab.1 The settling time (h) of hooks (1~25)

No. of branch time	1/25	2/24	3/23	4/22	5/21	6/20	7/19	8/18	9/17	10/16	11/15	12/14	13
Conventional hooks	0.16	0.23	0.34	0.45	0.55	0.63	0.72	0.77	0.88	0.95	1.00	1.08	1.13
Experiment-al hooks	/	0.20	0.29	0.38	0.47	0.53	0.61	0.65	0.74	0.80	0.85	0.91	1.01

1.3.2 Soak time and CPUE

To analyze the relationship between soak time and CPUE, the data of 50 sites were pooled. The maximum and minimum soak time of fishing gear was 22.8h and 4.6h, respectively. Soak time of fishing gear was divided into one hour interval so as to total branch lines and individuals of bigeye tuna and yellowfin tuna. For example, soak time was defined to 5h if it was between 4.5h and 5.5h. There were 19 intervals of time, 4h, 5h, 6h…, 23h and thus their corresponding $CPUE_{Tr}$ were calculated as:

$$CPUE_{Tr} = \frac{N_{Tr}}{F_{Tr}} \times 1000 \quad (12)$$

N_{Tr}: individuals in a defined interval; F_{Tr}: branch lines deployed in a defined interval.

Quadratic regression was used to fit the relationship between soak time and CPUE. The quadratic regression model was shown as follows. The optimum soak time of tuna longline fishing gear can be estimated afterwards.

$$y = ax^2 + bx + c$$

where a,b,c was the parameters,, x was the soak time, y was $CPUE_{Tr}$.

1.3.3 Catch estimating for defined interval

For a minority of catches, their caught time failed to be recorded because of complicated situation right at sea. To ensure the accuracy of calculation, data of catches with time recording were dealt with at first. For those of catches without time recording, they were assigned in proportion to the corresponding soak time. In that case, unusual data (the extremely maximum value or minimum value) should be got rid of.

We assumed n_s (s =5,6,⋯⋯23) was the catches with the time recording, f_t was catches of fish with time unrecording (t=1, for bigeye tuna; t=2, for yellowfin tuna).

So the estimating formula for catches with soak time unrecording was:

$$N_s = \frac{n_s}{\sum_{s=5}^{23} n_s} \times f_t \qquad (s = 5,6,\cdots 23; \qquad n_s \neq n_{samx} or\, n_{s\min}) \qquad (13)$$

When n_s was the maximum catches and minimum catches with time recording, we assumed $n_s = 0$.

2. Result

2.1 Analysis of soak time

In this study, the longest soak time was 22.8 h on December 6 while the shortest was 4.6 h on November 2. The amount of branch lines underwent considerable changes if soak time was 7 h below. The amount of branch lines remained constant (about 7000) when the soak time was between 7 h and 13 h. Moreover, the amount of branch lines decreased while the soak time was between 13 h and 23 h (Fig.4).

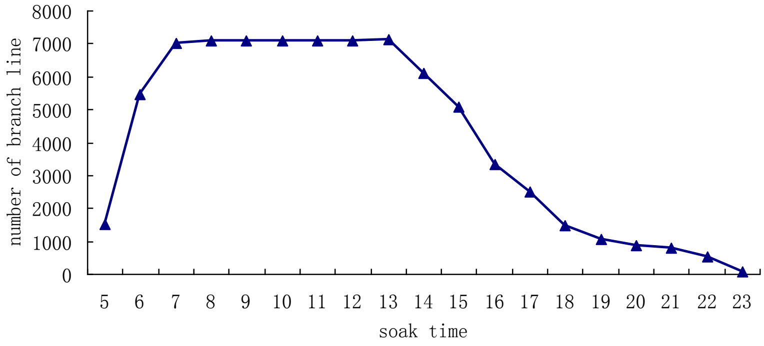

Fig.4 The distribution of branch lines in the soak time

2.2 Optimum soak time

The relationships between CPUE (y_t) of bigeye tuna and yellowfin tuna and soak time (x_t) were indicated in Fig.5 and can be described in quadratic regression as follows:

For bigeye tuna:

$$y_1 = -0.053x_1^2 + 1.2756x_1 - 3.702 \qquad R^2 = 0.8769 \qquad (14)$$

For yellowfin tuna:

$$y_2 = -0.0662x_2^2 + 1.4279x_2 - 3.8953 \qquad R^2 = 0.8321 \qquad (15)$$

Obviously, the CPUEs of bigeye tuna and yellowfin tuna increased with the increasing soak time at first. Then, the CPUEs of bigeye tuna and yellowfin tuna decreased with the soak time increasing. From the above formula 14 and 15, we can estimate that the CPUEs of bigeye tuna and yellowfin tuna reach the peak when the soak time was between 11.5 h and 12.5 h, and between 10.5 h and 11.5 h, respectively. However, it is noted that the increase of their CPUEs doesn't go with the increasing soak time. Instead, they decline.

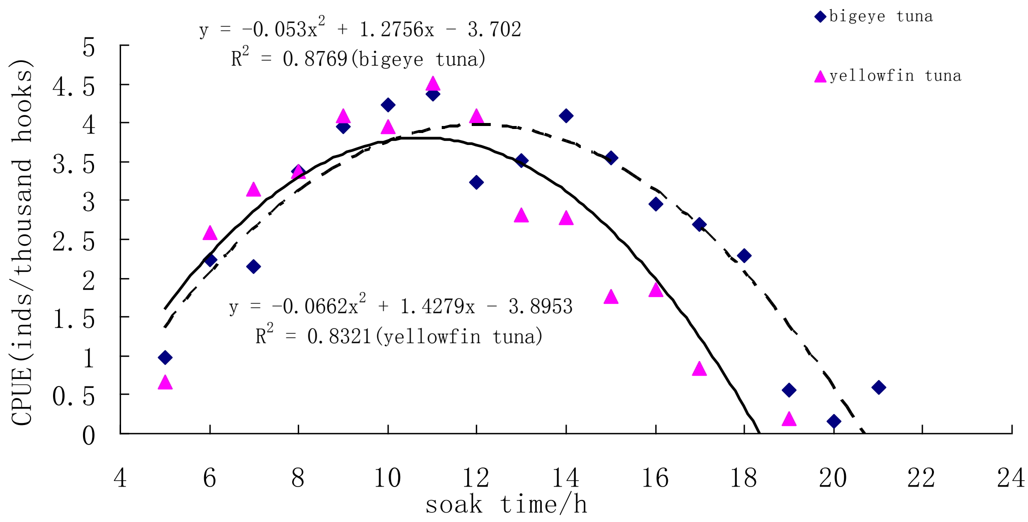

Fig.5 The regression curves between the CPUE of bigeye tuna and yellowfin tuna and soak time

3. Discussion

3.1 Calculation model of soak time for branch lines in longline fishery

The main factors affecting the soak time of each branch line were the time interval of deployment, mode of retrieval, the amount of branch lines and the time to start and finish with retrieval. The calculation model of soak time developed in this study for fishing gear might improve the accuracy to calculate the soak time for each branch line. The fishing effort influences a lot to fishing mortality and CPUE. The analysis of CPUE should accompany with the standardization of fishing effort (Zhan, 1995). Standardization of fishing effort and CPUE calls for proper variables, like time, space, fishing gear, and environment, with higher resolution, and need to couple with fish physiology and behaviour (Maunder and Punt, 2004). For tuna longline fishing, the amount of branch lines, the time of deployment, the period of waiting time and the mode of retrieval are taken into account if the soak time is considered to be fishing effort. Moreover, the duration of fishing gear soak time can be reflected in it. Therefore, the accuracy of CPUE will be improved while the soak time of branch lines is taken as fishing effort.

3.2 Soak time and CPUE

By the use of GLM model, Carruthers *et al*. (2011) analyzed how operation parameters and environment variables influenced the CPUEs of swordfish and blue shark. They proved that soak time had a great impact on the CPUEs of swordfish and blue shark. Ward and Myers (2004) concluded that the CPUEs of tuna and sea turtle were lower when soak time was 20h instead of 5h. Morgan and Carlson (2010) found that the catch rate of shark increased faster as it has been soaked for 5h to 12h in the Atlantic Ocean demersal longline fishery. Ogura *et al*. (1980) indicated that total catches of demersal longline fishery gradually decreased with time increasing. All of the above mentioned studies have demonstrated that soak time contributed a lot to CPUE. In Fig. 5, both CPUEs of bigeye tuna and yellowfin tuna presented increasing at first and then decreasing trend along the increase of soak time. Furthermore, the CPUEs of bigeye tuna and yellowfin tuna reach to the peak when soak time lasts for 11.5 h to 12.5 h and 10.5 h to 11.5h, respectively. Note that both related coefficient R^2 for the bigeye tuna and yellowfin tuna failed to reach 0.9, one was 0.8769 and the other was 0.8321. There were several reasons for it: (1) The corresponding fishing time of part of catches was unrecorded due to the complicated situations at sea. Among this, 69 were bigeye tuna, and 31 were yellowfin tuna. As a result, this may depress the accuracy of regression curve; (2) The line shooter speed and the vessel speed were assumed at a constant velocity because it was difficult to remain constant in practical operation.

3.3 Soak time influence on CPUE

The catch ability of longline fishing failed to keep increasing with the increasing of soak time. The reasons might be the effect of bait attraction faded and the hooked catches got lost (Svein *et al*.,1997). Fish is attracted by the smell because some substance of fish bait melted away and dissolved in water. The more substance of bait melts, the more catches are, and finally it gets the highest point. As time goes by, the bait has gradually eroded away, which decreases the attractiveness. Moreover, with much soak time, the hooked fish struggled and then escaped. What’s worse, the hooked fish would be preyed by such natural enemies as the whales and sharks.

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