Profile of Hook depth of Chinese Fresh tuna longline in the tropical Indian Ocean based on TDR data

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Abstract: This paper, based on data recorded by TDRs which were attached to the branch line of tuna longline operated by the Chinese fishing boats in the tropical high seas of the Indian Ocean from Sep.15th to Dec.12th 2005, describes the profile of the hook depth of tuna longline. 185 TDR data were used in this study. TDR recorded fishing depths of hooks are compared with the depths calculated by catenary algorithms. 9 types of catenary depth estimations (25 hooks totally per basket) were calculated with different line setting speed, boat speeds. Results showed that line setting speed affects the fishing depth of the hooks more than boat speed and current speed do. TDR data also indicates that fishing depth of a hook during soaking is not stable and the vertical fluctuation of a hook depth varies with the position of the branch line the hook connected. The vertical fluctuation tends to greater when the branch line the hook connected is closer the middle position of the basket line and reaches the maximum at the middle position of the basket line. TDR depth of hooks is shallower than catenary depth.

1 Introduction

The depth at which main targeting species are captured is fundamental to understanding the impacts of tuna longline operation on target and bycatch species (Bigelow et al., 2006). Knowledge of accurate vertical distribution of hooks in the water column leads to significant improvements in fishery oceanographic relationships, vertical distribution, habitat preferences, and stock assessments (Boggs, 1992; Brill and Lutcavage, 2001).

Actual fishing depth a hook could reach is determined by many factors, such as fishing materials, fishing operation parameters and etc. The optimal fishing depths for commercially important pelagic species caught on longlines could be determined in situ by instruments, such as sonar (Bullis, 1955), expendable bathy-thermographs (Matsumoto et al., 2001), micro-BTs (Okazaki et al., 1997; Mizuno et al., 1999), depth recorders (Saito, 1973; Hanamoto, 1974; Nishi, 1990), ultrasonic positioning system (Miyamoto et al., 2006) and temperature-depth recorders (Beverly, 2005;

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Bigelow et al., 2006) etc,. Hook depths with gear configuration can also be calculated by catenary geometry (Yoshihara, 1951, 1954), as theory predicts that a suspended line with equal vertical loading along its length will assume the shape of a catenary in the absence of corrupting factors (Bigelow et al., 2006).

This study attempts to describe the profile of hook depth of tuna longline and find out how the main operation parameters affect the depth and sinking process of hooks connected to branch lines along the basket line based on the TDR measurements conducted by the Chinese fresh tuna longliner operating in the tropical high seas of the Indian Ocean.

2 Materials and Methods

Investigation instruments include Submersible Data Logger XR-620 and 7 sets of TDR-2050 (RBR Co. Canada). The actual depth of hook approached and water temperature measured by TDR, the accuracy on depth measurement is ±0.05% with range of 10m-740m, and the accuracy on temperature is ±0.002□. Experiment was conducted on board Chinese fresh tuna longliners Huayuanyu No.18 and No.19 of Guangdong Huayuan Fisheries Group Ltd which operated at area of 0º47´N~10º16´N, 61º40´E~70º40´E (see Fig.1) from September 15 to December 12, 2005. The main dimensions of the boats are 26.12 m LOA , 150 GT, 407 kw of main engine. Setting of longline gear and position of TDR sensors are showed in figure 2. Attributes of the TDR-monitored tuna gear are given in Table 1.

Table 1 Operation parameters applied by Chinese tuna longliners in the tropical Indian Ocean (Sept. 15 – Dec. 12, 2005)

Operation parameters	Tuna longliner	
	Hua Yuanyu No. 18	Hua Yuanyu No. 19
Line shooter speed (m/s)	5.5~5.8	5.6~5.7
Vessel speed (knot)	8~8.5	8~8.5
Hooks per set	800~2600	800~2600
Hooks between floats	23~25	23~25
Float line (m)	22	22
Branch line (m)	12	12
Mainline (km)	110	110
Mainline diameter (mm)	3.5	3.5
Hook type	Ring hooks	Ring hooks

Hook size	4.5mm	4.5mm

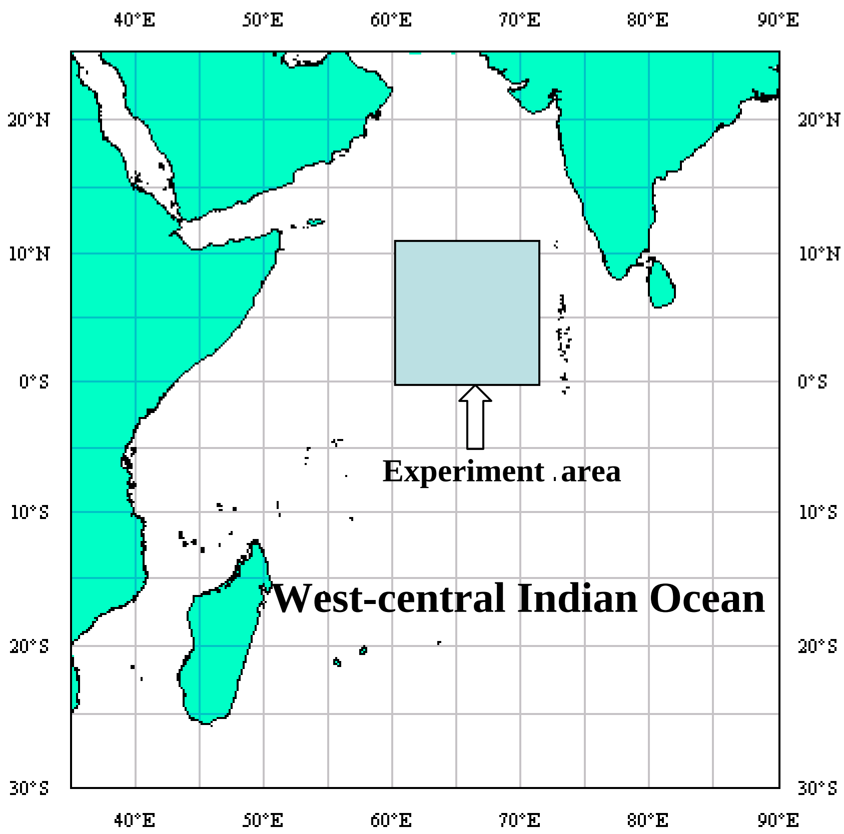

Figure 1.　Experiment area

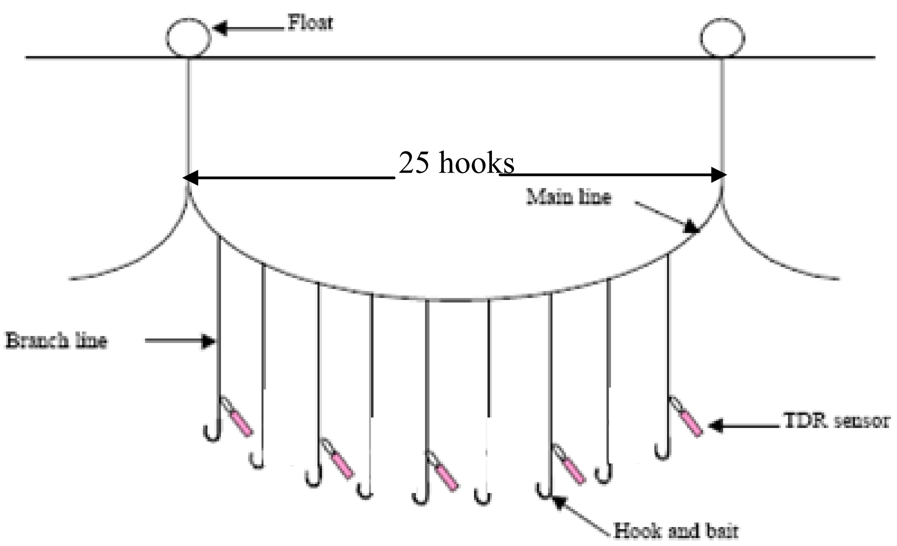

Figure 2. Scheme of longline configuration and position of TDR sensors (from Matsumoto (2001) with small change)

2.1 The depth measured by TDRs

The TDRs were programmed to automatically measure temperature and depth every 3 minutes. Temperature and depth data measured by TDR will log into computer immediately after hauling back. Profile of a hook is illustrated by means of RBR software.

2.2 Catenary depth estimation

The maximum depth is predicted based on the catenary algorithms as described by Yoshihara (1951, 1954).

$$D'_j = h_a + h_b + l\left[\sqrt{1+\cot^2\varphi_0} - \sqrt{\left(1-\frac{2j}{n}\right)^2 + \cot^2\varphi_0}\right] \qquad (1)$$

where D'_j is the depth of catenary hook (j), h_a the length of branch line, h_b the length of float line, l half of stretched length of the main line deployed between two consecutive floats, j the number of the catenary hook between floats (j =1,2,….25) and n is HBF (hooks between floats) + 1.

The angle (φ) between the horizontal and tangential line of the main line where the floatline was attached (degrees from horizontal) was taken from the relationship:

$$k = L/2l = \cot\varphi_0 sh^{-1}(\mathrm{tg}\varphi_0)$$

Where k is the sag ratio, L is the horizontal distance between successive floats.

Because the catenary angle could not be estimated for all TDR monitored sets, 30–85◦ is considered as appropriate angles, which corresponded to sag ratios ranging from 1.04 to 3.57 (Bigelow et al., 2006). Catenary depths were not estimated for sets with sag ratios outside of this range.

3 Results and discussion

A total of 519 TDR data were obtained during the research, among which 185 TDR data are sampled for analysis.

3.1 Sinking of hook

Sinking of hooks will to some extent affect the incidental catch of seabirds and sea turtles in tuna longline fisheries. Sinking movement of a hook is related to its relevant position between two floats. Figure 3 shows the sinking process of the hooks recorded from one longline setting (Nov. 23, 2005; 65°55E, 7°51N). It indicated that the similar fluctuation occurred to the 2nd and 3rd hook and similar pattern to the 4th, 5th and 6th hook. Fluctuation of hooks in vertical direction increases with increasing depth of hook's layout. Fishing depth of a hook changed with the soaking time. It seems that the fishing depth of a hook is deeper at first half time, shallower at the second half of soaking time. The difference in vertical depth could be as much as 50 meters, as the

6th hook indicated.

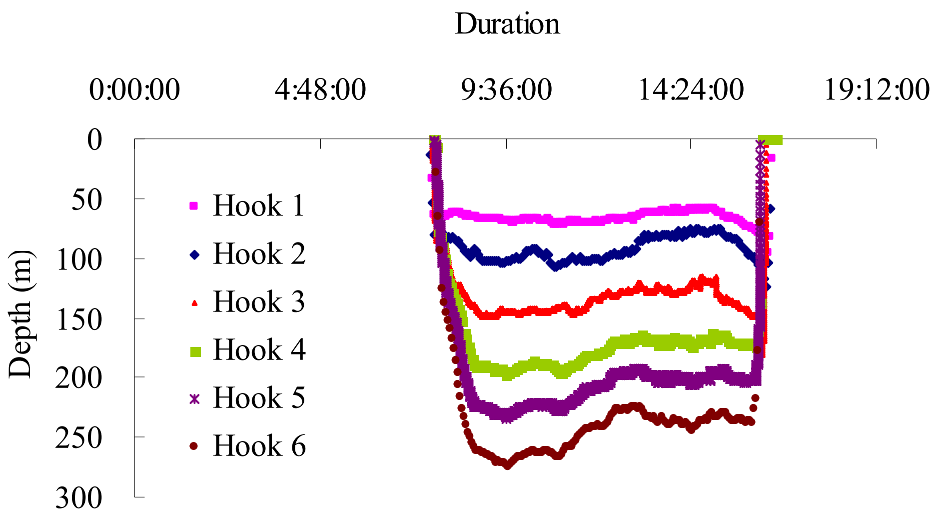

Figure 3. Example of depth trajectory of the branch line measured by TDR (in Nov. 23, 2005; 65°55E, 7°51N).

3.2 Catenary and measured depth estimation

Catenary depth was predicted based on the Yoshihama's method (n=98 sets). Figure 2 show 9 types of catenary depth estimations based on different line setting speed, boat speed and time interval for setting two successive hooks (see table 2) and the results showed in Figure 4.

The maximum predicted depth an individual hook can reach increases with the increase of line setting speed under the same vessel speed and interval for shooting two successive hooks, such as type A, B, C and D. When line setting speed and interval for shooting two successive hooks are constant, the predicted depth of a hook, however, decreases with the increase of vessel speed, as showed with type D, E and G. The catenary depth increases with the increasing interval for shooting two successive hooks under the same vessel speed and line shooter speed, such as type B and H.

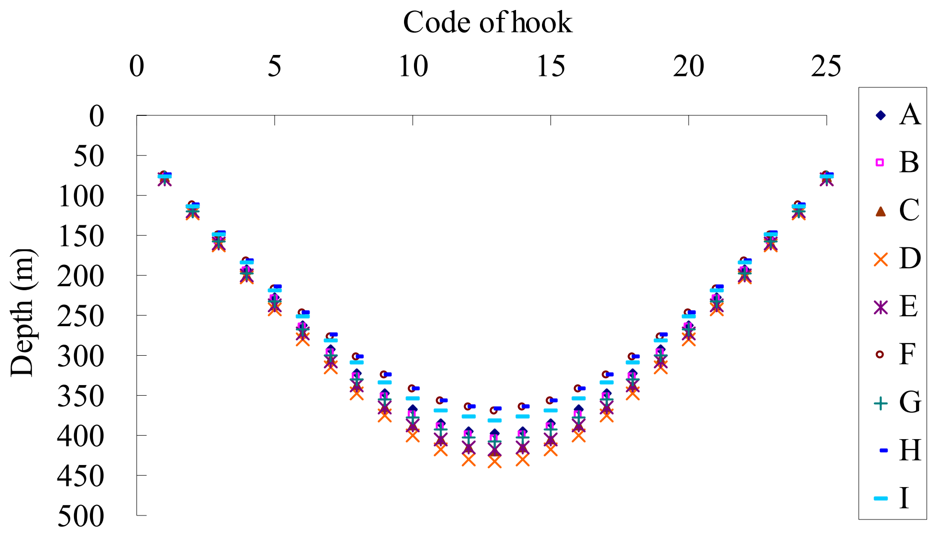

Figure 4. Catenary depth estimations of Chinese tuna longline in the tropical Indian Ocean (Sept. 15 to Dec. 12, 2005).

Table 2 Operation parameters used for catenary depth estimation of Chinese tuna longline in the tropical Indian Ocean (Sep. 15 to Dec. 12, 2005)

	A	B	C	D	E	F	G	H	I
Vessel speed (knot)	8	8	8	8	8.3	8.5	8.5	8	8.5
Line shooter speed (m/s)	5.5	5.6	5.7	5.8	5.8	5.5	5.8	5.6	5.7
Time interval between two continuous hook (s)	8	8	8	8	8	8	8	7.8	8

3.3 Comparison on the observed depth and the catenary depth

The observed depth of each hook that TDR attached was obtained. In order to compare the difference it may exist between the observed depth and the catenary depth, we used the calculated mean value of the hook depth. Results are showed in Figure 4.

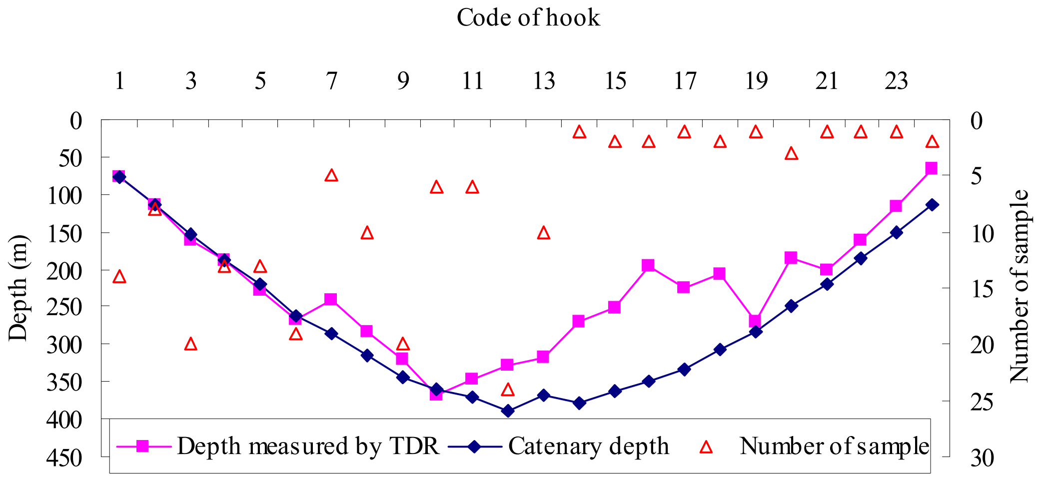

Figure 4.　Comparison between TDR depth and Caternary depth

According to 185 TDR measurements during the research, depth profiles of hooks are showed in table 3.　59 percent of the hooks fall into 200-400 m of water column. According to the caternary depth ,however, 71 percent of the of hooks fall into the above water column. It suggests that actual fishing depth is shallower than catenary depth.

Table 3.　Depth distribution of hooks measured by TDRs and catenary depth

Depth range (m)	0-100	101-200	201-300	301-400
Depth measured by TDR	8%	33%	38%	21%
Catenary depth	4%	25%	25%	46%

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