Depths of fish catches using shortening rates of tuna longline on board training ship Tenyo maru (235^{th} voyage) in 2015

Hideaki Tanoue *, Masahiko Mohri *, Takafumi Itoh **, Masataka Kokatsu **, Hiroshi Gotoh **, Taketomo Enoshima **, Kazuhiro Hata **, Yuuka Kawato *, Makoto Niitani ***, Yukio Okita ***, Satoshi Omi ***, Kiyohiko Fukami ***, Tadashi Kamano ***, Yoichi Gotoh ****, Wataru Miyashita ***

***National Fisheries University, Dept. of Fisheries Science and Technology, Japan**
**** National Fisheries University, Tenyo Maru, Japan**
***** National Fisheries University, Koyo Maru, Japan**
****** Marine Science High School, Kanagawa, Japan**

Abstract

Tuna longline fishing with a total of 2200 hooks was carried out on board the training ship Tenyo Maru in the Pacific Ocean, November 27 to December 2 in 2015. Using the longline shortening rates obtained from the data which had been recorded during the operations, each length of the main line, branch line, and float line, and the number of branch lines, the respective depths of the fish hooks with catches were calculated. During the six days (a total of six operations), seven fishes consisting of four different species were caught at the following calculated depths: two wahoo, *Acanthocybium solandri* and two shortnose spearfish, *Tetrapturus angustirostris* at 100–120 m, one *wahoo* and one swordfish, *Xiphias gladius* at 140–160 m, and one bigeye tuna, *Thunnus obesus* at 200–220 m.

1 Introduction

Tuna longline fishing is a fishing technique, where a long rope called a main line is attached at a regular interval with one end of each of multiple short ropes called a branch line, which is attached with a baited hook at the other end (Fig. 1). On the

Tenyo Maru, a training ship of National Fisheries University, the longline is handled with a method where fishing gear is neatly untangled every basket at cast and organized in order every basket at recovery, which is called “Mokko shiki” in Japan. This method is carried out by hand, and therefore it is a good practice for learning the principle of fishing method although the number of baskets to be cast becomes less compared with the line winding system or the reel system.

To increase the efficiency of longline fishing, it is necessary to understand the temperature, time zone, and depth where a target fish species inhabits [1]. Yoshihara [2]-[4] developed an equation for determining the depth of a hook in the water. Into this equation, by substituting each length of the main line, float line, and branch line, the number of branch lines per basket, and the consecutive number of the branch line with a fish catch which is counted from one side of the basket, the angle of inclination at the supporting point of the main line, which is difficult to be measured, can be expressed as a shortening rate indicating the degree of the sagging main line (Fig. 2).

National Fisheries University incorporates a practical training of tuna longline fishing on board a training ship in curriculum for fourth-year students and a one-year advanced course. This study shows the calculation data on the depths of hooks catching tunas, as a step toward investigation of the characteristics of fishes caught during the practical trainings of our university, based on the data of fishes caught and the longline used during the practical training on board a training ship “Tenyo Maru” in 2015.

2 Materials and methods

For six days from November 27 to December 2 in 2015, a practical training for tuna longline fishing was carried out on board the Tenyo Maru, a practical ship of National Fisheries University.

In this training, two types of longline gear, shallow-set and deep-set ones, were adopted: the former was attached with five branch lines (with hook) per basket (main line: 300 m, branch line: 27m, float line: 30 m) and the latter was attached with ten branch lines (with hook) per basket (main line: 550 m, branch line: 27m, float line: 30 m). Furthermore, a small submarine bathythermograph (SBT) was attached on each of the multiple branch lines to check the construction of the longline fishing gear.

The depth of each hook D (m) used in this study is calculated using the following equation developed by Yoshihara [2]-[4] assuming that the main line forms a catenary when the longline is in the water:

$$D = ha + hb + \ell\left\{\sqrt{1+\cot^2\varphi_0} - \sqrt{\left(1-\frac{j}{n}\right)^2+\cot^2\varphi_0}\right\} \qquad (1)$$

where ha is the length of the branch line, hb is the length of the float line, ℓ is half the length of the main line, n is the number of branch lines in one basket, and j is the consecutive number of the branch line counted from one side of the basket.

The angle of inclination φ_0 at the supporting point of the main line, which is difficult to be measured, is replaced with a shortening rate k indicating the degree of the sagging main line. The shortening rate k is obtained by the following equation,

$$k = vt/2\ell m \qquad (2)$$

where v is the vessel speed, t is the hours required to set lines, and m is the number of baskets.

By substituting the value of k obtained from the equation (2) into the following equation (3),

$$k = \cot\varphi_0 \sinh^{-1} \tan\varphi_0 \qquad (3)$$

The value of φ_0 is obtained. By substituting φ_0 into the equation (1), the hook depth D is determined. The calculation of the inclination angle φ_0 is based on the figures and tables shown by Yoshihara [4].

3 Results

During the six longline fishing operations, we caught seven fishes consisting of four different species: three wahoo, two shortnose spearfish, one swordfish, and one bigeye tuna. Table 1 shows the results of each depth calculated for the fishes caught: three wahoo were caught at 105 m, 105 m, and 147 m, two shortnose spearfish were both at 104 m, swordfish and bigeye tuna were at 150 m and 219 m, respectively.

4 Discussion

The depth calculated for bigeye tuna caught during this operation was 219 m, which was the deepest among all of the depths calculated for the fishes caught. The water layers where wahoo and swordfish were caught are shallower than that of bigeye tuna, and therefore it is considered that bigeye tuna should be targeted at the deeper layer to avoid bycatch of the other species.

In this study, SBTs enable the measurement of each hook depth of the multiple branch lines. Table 2 shows the comparison between the hook depths of the branch lines measured by SBTs and those of the same ones calculated using shortening rates. As for each depth of the hooks used for the comparison, 17 out of 18 hooks, whose depths are calculated using shortening rates, show deeper values than the average depths measured by SBTs.

SBT enables a sequential measurement of a hook depth every second, whereas the depth calculated using the shortening rate is assumed that the lines remain stable during the time between casting and recovery. Therefore, SBTs have a tendency to indicate the shallower depth compared with the calculation using the shortening rate because they measure the hook depth in the vicinity of the sea surface immediately after casting and at recovery. In addition, phenomena such as drifting of the longline occur due to a flow in the water, whereas the depths calculated using shortening rates do not reflect such phenomena.

Shortening rate enables a simplified measurement of a hook depth. Therefore, taking the above-mentioned characteristics into consideration, it is indispensable to advance the studies on the relationship between the depths calculated using shortening rates and the corresponding fish catches.

5 Acknowledgements

We thank the crew of the training vessel "Tenyo maru" from National Fisheries University.

References

[1] E. Hanamoto (1987) Effect of Oceanographic Environment on Bigeye Tuna Distribution. *Bulletin of the Japanese Society of Fisheries Oceanography*, 51, 203-216.

[2] T. Yoshihara (1951) Distribution of Fishes caught by the Long Line Ⅱ. Vertical Distribution. *NIPPON SUISAN GAKKAISHI*, 16, 370-374. (Japanese)

[3] T. Yoshihara (1952) Distribution of Fishes caught by the Long Line Ⅲ. Vertical Distribution. *NIPPON SUISAN GAKKAISHI*, 18, 187-190. (Japanese)

[4] T. Yoshihara (1954) Distribution of Fishes caught by the Long Line Ⅳ. Vertical Distribution. *NIPPON SUISAN GAKKAISHI*, 19, 1012-1014. (Japanese)

Received August 16, 2016
Accepted January 4, 2017

Academic backgrounds:

Hideaki Tanoue:

04/1997 – 03/2001	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2002 – 03/2004	Master's course of Graduate School of National Fisheries University, Shimonoseki, Japan
04/2005 – 03/2009	Doctor's course of Graduate School of The University of Tokyo, Tokyo, Japan
04/2009 – 03/2010	Ocean Research Institute, The University of Tokyo, Japan
04/2010 – 03/2011	Atmosphere and Ocean Research Institute, The University of Tokyo, Kashiwa, Japan
04/2011 – 03/2013	Policy Research, Ocean Policy Research Foundation ,Tokyo, Japan
04/2013 – present	Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan
Research field:	Behaviour, Ecology and Observation systems, Fisheries resources management, Integrated Costal Management

Masahiko Mohri:

04/1983 – 03/1987	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1987 – 03/1988	Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1988 – 03/1990	Master's course of Graduate School of Tokyo University of Fisheries, Tokyo, Japan
04/1990 – 03/1991	Doctor's course of Graduate School of Tokyo University of Fisheries, Tokyo, Japan
04/1991 – present	Department of Fishery Science and Technology, National Fisheries University, Shimonoseki, Japan
Research field:	Fisheries information analysis

Takafumi Itoh:

04/2006－03/2010	Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2010－03/2011	Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki,

Japan
04/2011-present Crew of Fisheries Agency
Research field: Navigation

Masataka Kokatsu:
04/2002－03/2006 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2006－03/2007 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2007-present Crew of Fisheries Agency
Research field: Navigation

Hiroshi Gotoh:
04/1998－03/2002 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2002－03/2004 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2004-present Crew of Fisheries Agency
Research field: Navigation

Taketomo Enoshima:
04/1990－03/1994 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1995－03/1996 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1996-present Crew of Fisheries Agency
Research field: Navigation

Kazuhiro Hata:
04/1980－03/1985 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1985－03/1986 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1996-present Crew of Fisheries Agency
Research field: Navigatio

Yuuka Kawato:
04/2007－03/2011 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2011－03/2012 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2012-present Crew of Fisheries Agency
Research field: Navigation

Makoto Nitani:
04/1996－03/2000 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2000－03/2001 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2001-present Crew of Fisheries Agency
Research field: Navigation

Yukio Okita:
04/1995－03/1999 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1999－03/2000 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/2000-present Crew of Fisheries Agency
Research field: Navigation

Satoshi Omi:
04/1989－03/1993 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1993－03/1994 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1994-present Crew of Fisheries Agency
Research field: Navigation

Kiyohiko Fukami:
04/1986－03/1990 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1990－03/1991 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1991-present Crew of Fisheries Agency
Research field: Navigation

Tadashi Kamano:
04/1980－03/1984 Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1984－03/1985 Advanced course of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
04/1996-present Crew of Fisheries Agency
Research field: Navigation

Yoichi Gotoh:
04/1993 – 03/1997 Undergraduate course of Department of Fishery Science and Technology of Shimonoseki University of Fisheries, Shimonoseki, Japan
04/1997 – 03/1998 Advanced course of Fishery Science and Technology of Shimonoseki University of Fisheries, Shimonoseki, Japan
04/1998 -present Marine Science High School, Kanagawa, Japan
Research field: Navigation

Wataru Miyashita:
04/2013 – present Undergraduate course of Department of Fishery Science and Technology of National Fisheries University, Shimonoseki, Japan
Research field: Navigation

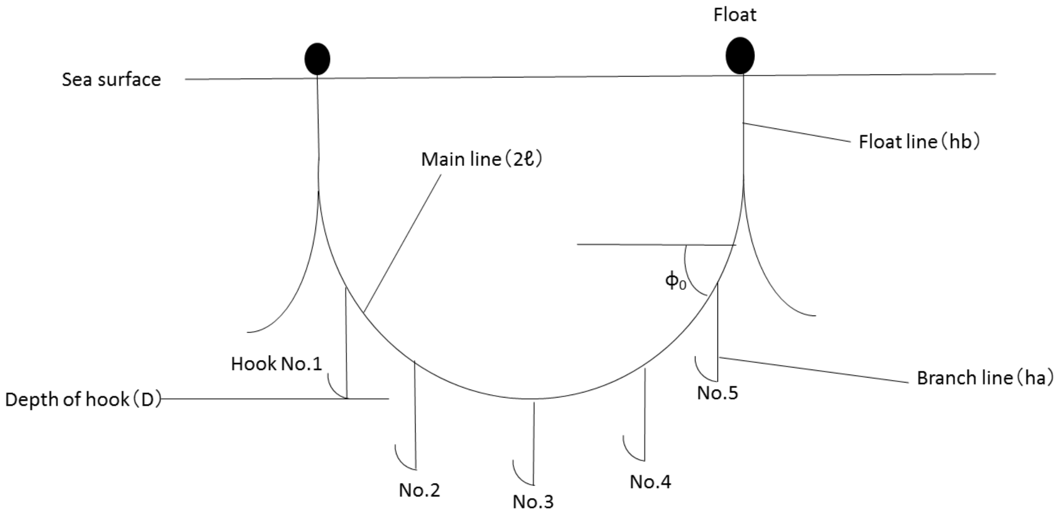

Fig. 1 Schematic diagram of tuna longline.

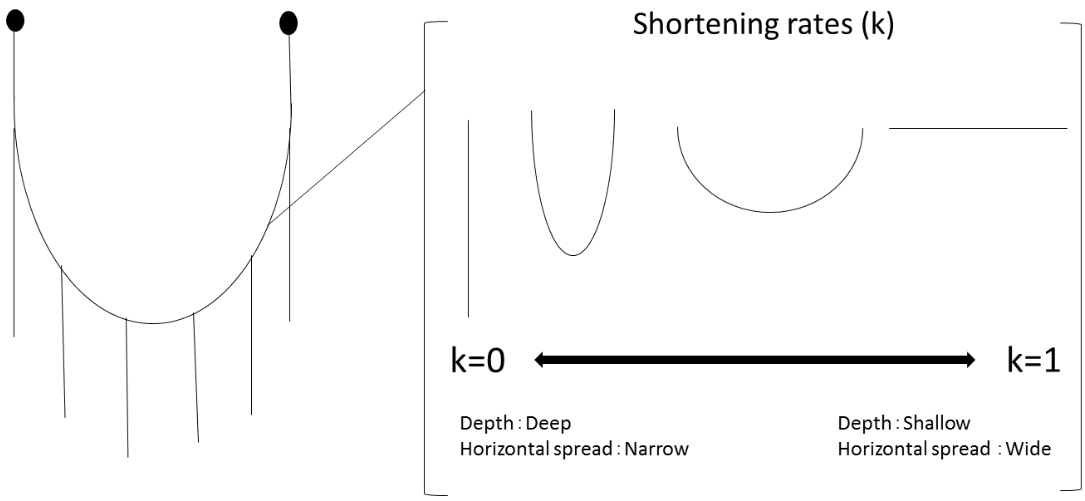

Fig. 2 Configuration of shortening rates (k).

Table 1 Fish caught and depth using shortening rates.

Day	Species	Depth of hook (m)
2015/11/27	wahoo	105
2015/11/29	wahoo	147
	shortnose spearfish	104
2015/11/30	wahoo	105
2015/12/1	shortnose spearfish	104
	swordfish	150
2015/12/2	bigeye tuna	219

Table 2. Depth of hook using shortening rates and SBT.

Number of hook	Depth (m)	
	Shortening rates	SBT
2015/11/29	(Shallow-set, k = 0.56)	
No.1	104	97
No.2	147	127
No.3	170	130
No.4	147	116
No.5	104	92
2015/11/30	(Deep-set, k = 0.59)	
No.6	278	223
No.7	245	215
No.8	201	192
No.9	154	151
No.10	105	98
2015/12/1	(Depth-set, k = 0.67)	
No.6	257	237
No.7	232	225
No.8	194	194
No.9	150	156
No.10	104	103
2015/12/2	(Shallow-set, k = 0.67)	
No.1	102	96
No.2	143	118
No.3	163	139