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


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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:

\[
D = h_a + h_b + \theta \left\{ \sqrt{1 + \cot^2 \varphi_0} - \sqrt{\left(1 - \frac{j}{m}\right)^2 + \cot^2 \varphi_0} \right\}
\]

(1)
where $h_a$ is the length of the branch line, $h_b$ is the length of the float line, $\ell$ 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 $\varphi_0$ 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,

$$k = \frac{vt}{2\ell m} \tag{2}$$

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),

$$k = \cot \varphi_0 \sinh^{-1} \tan \varphi_0 \tag{3}$$

The value of $\varphi_0$ is obtained. By substituting $\varphi_0$ into the equation (1), the hook depth $D$ is determined. The calculation of the inclination angle $\varphi_0$ 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.

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References

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<th>Name</th>
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<th>Research field</th>
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Fig. 1  Schematic diagram of tuna longline.
Fig. 2  Configuration of shortening rates (k).

Table 1  Fish caught and depth using shortening rates.

<table>
<thead>
<tr>
<th>Day</th>
<th>Species</th>
<th>Depth of hook (m)</th>
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<tbody>
<tr>
<td>2015/11/27</td>
<td>wahoo</td>
<td>105</td>
</tr>
<tr>
<td>2015/11/29</td>
<td>wahoo</td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>shortnose spearfish</td>
<td>104</td>
</tr>
<tr>
<td>2015/11/30</td>
<td>wahoo</td>
<td>105</td>
</tr>
<tr>
<td>2015/12/1</td>
<td>shortnose spearfish</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>swordfish</td>
<td>150</td>
</tr>
<tr>
<td>2015/12/2</td>
<td>bigeye tuna</td>
<td>219</td>
</tr>
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Table 2. Depth of hook using shortening rates and SBT.

<table>
<thead>
<tr>
<th>Number of hook</th>
<th>2015/11/29 (Shallow-set, k = 0.56)</th>
<th>2015/11/30 (Deep-set, k = 0.59)</th>
<th>2015/12/1 (Depth-set, k = 0.67)</th>
<th>2015/12/2 (Shallow-set, k = 0.67)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Depth (m)</td>
<td>Shortening rates</td>
<td>SBT</td>
<td>Depth (m)</td>
</tr>
<tr>
<td>No.1</td>
<td>104</td>
<td>97</td>
<td>237</td>
<td>102</td>
</tr>
<tr>
<td>No.2</td>
<td>147</td>
<td>127</td>
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<td>No.3</td>
<td>170</td>
<td>130</td>
<td>194</td>
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<td>No.4</td>
<td>147</td>
<td>116</td>
<td>194</td>
<td></td>
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<tr>
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<td>104</td>
<td>92</td>
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