EXPERIMENTAL FISHING TEST ON THE EFFICIENCY OF DOUBLE GILL NET

Masatsune Nomura*
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Introduction

Use of nylon cord for gill nets has become increasingly popular among fishermen because its greater pliability and less visibility under water than ordinary materials have been proved advantageous for promoting fishing efficiency. Along with this progress in material, construction of the gear has also made a notable improvement by adopting the so-called trammel type to bottom gill nets.

Of several merits the trammel net has, one is that it can entangle fish without so much selectivity of size of fish as in ordinary single gill nets. In another advantage, we may be able to alleviate inclination of the net due to current, and thus to extend an effective width of the net, for it has both buoyancy and sinking power greater than the single gill net. The fact suggests a possibility where the trammel net is operated not only in a current suitable for the single net but under stronger one, as well. On the other hand, some of disadvantage the trammel net has consist in difficulties of handling it when casting or hauling it up, removing the catches, repairing and so forth. Therefore, this mode of net construction can not be recommended for ordinary drift nets which are supposed to seize a large amount of fishes—say, sardine—at a time. Nevertheless, in other types of fisheries, the trammel net may be like to demonstrate reasons for which it may be superseded for the single drift net. Up to the present time, single drift net has been a major type of gear in northern North Pacific for salmon fishing. As yet the ratio of salmon falling off the net has been supposed to be some extent partly due to the mesh size unfitted for some individuals and partly due to a failure in perfectly entangling the catch. Moreover, the density of fish distributed in that part of the sea is comparatively thin so that the mean amount of catch per unit of drifters remains only at about ten individuals. Judging from these points, it is worthy of investigation whether or not the efficiency of salmon fishing can be risen by the use of trammel net. With this view in mind, the author carried out preliminary experiments to deduce fishing efficiency of the trammel net at a fish farm of the Tokyo University of Fisheries, at Ōizumi, Nagano Prefecture in November 1958, using the rainbow trout Salmo irideus (Gibbons) reared there.

Method and condition of the experiments

In discussing the function of trammel net, use of a double net is thought to be convenient for the experimental purpose. Because the double net will be enable us to examine difference in fishing efficiency between large mesh webbing on one side and small mesh webbing on the other as fish approach to either side of the net.

In the experiments five units of the double nets had each different small mesh webbing from the others in regard to either slackening \( b \) against the large mesh webbing, shortening \( s \), or mesh size \( L \), though the net \( N_{D2} \) is regarded as the standard type in these experiments. The value of \( b \) is represented by the ratio of the width of small mesh webbing against the width of large mesh webbing when the both are hanged individually in vertical under the condition of given shortening in horizontal respectively. An ordinary gill net (hereinafter called the single net) has been used as the control. The values of these characters are indicated in Table 1.

Table 1. Construction of small mesh net used for the experiment

<table>
<thead>
<tr>
<th>Type of net</th>
<th>Slackening ( b )</th>
<th>Shortening ( s )</th>
<th>Mesh size ( L )</th>
<th>Width x length (number of mesh)</th>
<th>Tank</th>
<th>Date (1958)</th>
<th>Testing time</th>
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<tbody>
<tr>
<td>Single Net</td>
<td>( N_S )</td>
<td>0.45</td>
<td>1.8sun*</td>
<td>20 x 132</td>
<td>P</td>
<td>(11.12, 11.13, 11.14)</td>
<td>17.00-22.00</td>
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<td></td>
<td></td>
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<td>(5.45cm)</td>
<td></td>
<td>Q</td>
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<tr>
<td></td>
<td>( N_{D1} )</td>
<td>1.1</td>
<td>0.55</td>
<td>19 x 168</td>
<td>P</td>
<td>(11.11, 11.12, 11.13)</td>
<td>17.00-22.00</td>
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<td>Q</td>
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<tr>
<td></td>
<td>( N_{D2} )</td>
<td>1.3</td>
<td></td>
<td>23 x 168</td>
<td>P</td>
<td>(11.10, 11.11, 11.12)</td>
<td>17.00-22.00</td>
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<tr>
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<td></td>
<td></td>
<td>Q</td>
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<tr>
<td>Double Net</td>
<td>( N_{D3} )</td>
<td>1.5</td>
<td></td>
<td>26 x 168</td>
<td>P</td>
<td>(11.13, 11.14, 11.15)</td>
<td>17.00-22.00</td>
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<td>Q</td>
<td></td>
<td>03.00-06.00</td>
</tr>
<tr>
<td></td>
<td>( N_{D4} )</td>
<td>1.3</td>
<td>0.45</td>
<td>24.5 x 132</td>
<td>P</td>
<td>(11.14, 11.15)</td>
<td>17.00-22.00</td>
</tr>
<tr>
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<td>03.00-06.00</td>
</tr>
<tr>
<td></td>
<td>( N_{D5} )</td>
<td>1.3</td>
<td>0.55</td>
<td>1.4sun (4.24cm)</td>
<td>P</td>
<td>(11.14, 11.15)</td>
<td>17.00-22.00</td>
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<td></td>
<td></td>
<td>Q</td>
<td></td>
<td>03.00-06.00</td>
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</table>

* One sun equals 3.03 cm.

Amilan (Toyo nylon) 210 D/6, was used for the single net as well as the small mesh webbings of the double nets. The scale of the completed double nets may be represented by that of the large mesh webbings which had the same specifications among the five units as follows:
Material: Amilan 210 D/9
Mesh size: 7.2 sun (21.8 centimeters)
Shortening: 30 percent
Completed length: 4 meters
Completed width: 1 meter.

The accessories consisted of: float line, 16 monme twine, single with 20 pieces of synthetic float, each having buoyancy of 25 gr.; lead line, 3 monme twine, single, with 70 pieces of lead each weighing 4.3 gr. under water.

Two concrete tanks, P and Q, were used. Their dimensions were about 25×5×2 meters with the depth of water being 1.4 meters. In tank P 1,200 individuals of the rainbow trout were released, and 600 in tank Q. The average body length of the former was a little smaller than what seems to fit to the mesh size of 1.8 sun (5.45 centimeters), while the latter were fairly larger.

In order to avoid the influence of moon light, the experiments were conducted for about a week with the lunar chosen at the center of the period. Every day any one of the nets was tested in either one of the tanks, first for five hours from 17-00 till 22-00 involving evening twilight and subsequently for another three hours from 03-00

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Fig. 1. Fishing condition in tank Q according to the time from 03.00 to 06.00 hours (example).
till 06-00 involving morning twilight. The net was made to float at the middle of the tank and kept clear off the walls and the bottom. Two strings, each fastened to either end of the float line, were held by hand on two sides of the walls. Thus, a shock produced by fish touching the net was transmitted to the hand with a pretty good sensibility. This shock was counted as “touch” to distinguish it from “catch”. The catch, though it took place in various parts of the net, was larger in number at the lower portion than the upper.

Whenever the observers felt the shock, the net was slowly pulled out of the water. A fish caught was removed from the net and released again into the tank. Observation data put in record include: time of fishing, part of net, part of the body or status entangled, swimming direction when fish made contact with the net, symbol “+” denoting the direction from small mesh side to large mesh, and “−” vice versa. The numbers of fish that fell off the net half-way were separately noted as “drop”. As an example, an accumulated numbers of fish according to the time elapsed in the morning in tank Q are shown in Fig. 1.

Discussion on the results

The relations between the length and gill circle of the fish population were determined as plotted in Fig. 2 on the basis of 100 individuals sampled at random by a dip-net from tank P, and fifty from tank Q, both representing nearly 10 percent of the
stock in either tank.

In the measurement, the body length (from the tip of the snout to the posterior end of the vertebra) was used for fish from tank P, and the fork length (from the snout to the cartilaginous median part of the caudal fork) for fish from tank Q. In the following discussion, the length of fish should refer to either one of these measurements depending on the source of fish specified.

Fig. 3 shows the length distributions of the sampled fish and of those caught in each experiment. According to a previous study (Nomura, 1959) dealing with relation

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**Fig. 3.** The length distributions of the rainbow trout population in the tanks and of fishes caught by experiments.

- : length distribution of fish sampled by scooping
- : length distribution of fish caught by entangling
- : length distribution of fish caught by gilling

Bracket shows the length range suitable for 5.5 centimeter mesh.
of the gill circle of fish to certain mesh size, optimal gill circle to a 5.5-centimeter (1.8 sun) mesh can be roughly calculated as 9.5 to 10.5 centimeters. By reference to Fig. 2 this can be converted into an optimal length, which is 17 to 19 centimeters in the body length for the group in tank P and 19 to 21 centimeters in the fork length for the group in Q. Since the group P had the mode of length distribution at 16 to 17 centimeters, while the group Q at 27 to 28 centimeters (Fig. 3), the former was a little smaller, and the latter fairly larger, than the optimal size of the mesh referred to above. Thus, the fish in the both tanks looked possessing satisfactorily requirements needed for investigating differences in mesh selectivity of the gill nets under test.

1. Characteristics of the nets relevant to length distribution

As is evident from Fig. 3, the mode of length distribution of catches by the single net was nearly the same with the optimal length calculated for the 5.5 centimeter mesh. In case of the group Q large-sized fish, the length range produced by the single net was considerably narrower than the length range by anyone of the double nets, with a few catches entangled in net being somewhat larger than the average. This was quite natural for the single net in view of its fishing function. On the other hand, efficiency of the double nets was higher for large fish of group Q than for those having

Table 2. Characteristic values showing relative

<table>
<thead>
<tr>
<th>Tank P</th>
<th>$C_G$</th>
<th>$C_T$</th>
<th>$D$</th>
<th>$A$</th>
<th>$T$</th>
<th>$f$</th>
<th>$f'$</th>
<th>$C_G$</th>
<th>$C_T$</th>
<th>$D$</th>
<th>$(C)$</th>
<th>$(C_T)$</th>
<th>$(C)$</th>
<th>$(C_T)$</th>
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<td>$N_S$</td>
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<td>$N_D3$</td>
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</table>

Heavy numerals indicate the number of fish gilled ($C_G$), trammelled ($C_T$), dropped ($D$), touched ($A$) or total of these ($T$).
the optimal size to the 5.5-centimeter mesh. However, there was no appreciable difference between the double and the single nets in catching the smaller fish in tank P. When \( N_{D2} \) and \( N_{D3} \) of the double nets in tank P are compared with each other, the latter net with smaller mesh appears to control the length of fish more strongly than the former. Further comparison between \( N_{D2} \) and \( N_{D1} \) with reference to slackening \( b \), and between \( N_{D2} \) and \( N_{D4} \) in regard to shortening \( s \) revealed that the mode of length distribution tends to incline to the smaller side when the values of \( b \) or \( s \) becomes lower than those of \( N_{D2} \).

2. Analyses of Fishing Efficiency

In detailed examinations of fishing efficiency of the nets under study, important factors that have to be considered may be expressed in the following formulae:

\[
\text{Fishing rate: } f = \frac{C_g + C_r}{T} = \frac{C}{T},
\]

where \( C_g \): the number of gilled fish,
\( C_r \): " " trammed fish,
\( C \): " " catch,
\( T \): the sum of fish including catch, "drop" and "touch".

efficiency of each net in the experiment.

<table>
<thead>
<tr>
<th>( C_g )</th>
<th>( C_T )</th>
<th>( D )</th>
<th>( A )</th>
<th>( T )</th>
<th>( f )</th>
<th>( f' )</th>
<th>( \frac{C_g}{C_T} )</th>
<th>( \frac{D}{C+D} )</th>
<th>( \frac{C}{C+D} )</th>
<th>( \frac{C_T}{C+D} )</th>
<th>( \frac{D}{C+D} )</th>
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<tr>
<td>23</td>
<td>6</td>
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</tbody>
</table>

+: Fish coming from small mesh net

-: Fish coming from large mesh net.
Assumed fishing rate: \( f' = \frac{C_0 + C_T + D}{T} = \frac{C + D}{T} \).

where \( D \) is the number of “drop”.

Ratio of gilled fish to trammeled fish: \( C_0/C_T \).

Ratio of “drop” to catch: \( \frac{D}{C+D} \).

Fishing ratio when fish comes from small mesh side (+): \( \left( \frac{C}{C+D} \right)_+, \left( \frac{C_T}{C+D} \right)_+ \).

Fishing ratio when fish comes from large mesh side (-): \( \left( \frac{C}{C+D} \right)_-, \left( \frac{C_T}{C+D} \right)_- \).

The values of these factors have been computed on the basis of the data from every experiment, and summed up values in the morning and in the evening according to respective net and tank as indicated in Table 2. In the table, \( A \) represents the number of “touch.”

1). Comparative values between the single net and double nets.

Of all the nets under report, the single net had fishing rate, \( f \), at the lowest, especially in tank Q which contained comparatively large individuals. In tank Q, moreover, the net presented the ratio of “drop”, \( \frac{D}{C+D} \) expressively large, and the value of \( C_0/C_T \) high as well. These are the points that make a difference between the single net and the double ones. The reason of the difference may be attributed to a limited function of the single net as it would offer few chances for catching fish though they may touch the net; even if fish had been in a state of being caught in the net, they were liable to drop half-way during hauling up the net. In fact, most of catches were found in a gilled state but rarely trammeled.

2). Effects of different slackening, shortening, or small mesh-size compared between \( N_{D1} \) and the other double nets.

With reference to the values in Table 2. comparisons have been made between: different slackening \( b \) which is 1.1, 1.3 or 1.5 for \( N_{D1} \), \( N_{D2} \), or \( N_{D3} \), respectively: different shortening \( s \) which is 0.55 for \( N_{D2} \) and 0.45 for \( N_{D4} \): different small mesh-size \( L \), 5.45 centimeters for \( N_{D2} \) and 4.24 centimeters for \( N_{D5} \).

Except these items specified above, the net had the same conditions with one another. From the results summarized in Table 3, it can be concluded that anyone of the double nets surpasses the rest in fishing function when it has either slackening, shortening, or size of small mesh, larger than the others.

In the both tanks, fishing ratio from small mesh side, \( (C_0/D)_+ \), is higher than the ratio from large mesh side, \( (C_0/D)_- \).

This fact indicates the “special character of fishing function of double nets.

3. The value of \( m \) based on the areal margin of small mesh net versus large mesh net in double net construction.

Here let us calculate an assumed value \( m \) that represents the ratio of area of small
Table 3. Comparative functions of a net different from the others

<table>
<thead>
<tr>
<th>Distinction of a net from the others</th>
<th>Fishing rate ( f )</th>
<th>Rate of &quot;drop&quot; ( \frac{D}{C+D} )</th>
<th>Ratio of gilled to trammelled ( \frac{C_o/C_T}{C+D} )</th>
<th>Fishing from small mesh ( \frac{C}{C+D} )</th>
<th>Fishing from large mesh ( \frac{C}{C+D} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank P (fish size comparatively small)</td>
<td>larger in slackening</td>
<td>larger in slackening</td>
<td>larger* in mesh</td>
<td>larger in slackening</td>
<td>larger* in mesh</td>
</tr>
<tr>
<td>Tank Q (fish size pretty large)</td>
<td>obscure</td>
<td>large</td>
<td>obscure</td>
<td>small</td>
<td>small</td>
</tr>
</tbody>
</table>

* The mesh size of so-called "large in mesh" is a little larger than the gill circle of fish in tank P and "smaller in mesh" is a little smaller.
mesh net to area of large mesh net when both have the same 30 percent shortening, and this can be obtained by the following procedure. Now, a double net is constructed with,

(a) shortening of large mesh net at 30 percent,
(b) shortening of small mesh net as 100s percent,
(c) vertical slackening of small mesh net against large mesh net denoted as b,
(d) large mesh net is spread in square unit area \( r^2 \).

The length of small mesh net \( l \) stretched in the horizontal direction equals as

\[
\frac{r}{1-s} \quad \text{When \( l' \) denotes \( l \) shortened by 30 percent,}
\]

\[
l' = \frac{r}{1-s} \times 0.7.
\]

As to the width of small mesh net \( b \times r \) under shortening \( s \) is

\[
b \times r = a \times n \sqrt{2s-s^2},
\]

where \( a \) is the mesh size, and \( n \) the number of meshes along the width of the net. The width vertically stretched is

\[
a \times n = \frac{b \times r}{\sqrt{2s-s^2}},
\]

therefore, the vertical length of small mesh net shortened by 30 percent, \( l'' \), is

\[
l'' = \frac{b \times r}{\sqrt{2s-s^2}} \times 0.71.
\]

Then, the value of \( m \) can be given as

\[
m = \frac{l' \times l''}{r^2} = \frac{0.7}{1-s} \times \frac{r \times 0.71 \times b \times r}{2s-s^3} = \frac{b}{2(1-s)\sqrt{2s-s^2}}.
\]

The values of \( m \) computed for the double net under study according to respective \( s \) and \( b \) are given in Table 4. Fig. 4 shows the relation between these values of \( m \) and \( f, C_0/C_r, \left( \frac{C}{C+D} \right)_+, \) and \( \left( \frac{C_r}{C+D} \right)_+ \) as in Table 2.

<table>
<thead>
<tr>
<th>( N_{D1} )</th>
<th>( N_{D4} )</th>
<th>( N_{D2} )</th>
<th>( N_{D3} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S )</td>
<td>.55</td>
<td>.45</td>
<td>.55</td>
</tr>
<tr>
<td>( b )</td>
<td>1.1</td>
<td>1.3</td>
<td>1.3</td>
</tr>
<tr>
<td>( m )</td>
<td>1.37</td>
<td>1.40</td>
<td>1.61</td>
</tr>
</tbody>
</table>
In Fig. 4 it is evident that these are nearly linear relationship between these values. Particularly the fishing rate, \( f \), becomes greater with the increase in the value of \( m \), at least within the range of \( m \) shown in Table 4.

In the above discussion, \( s \) has been used as the horizontal shortening and \( b \) as the vertical slackening. If we make another expression about this same construction of net such as \( s' \) expresses the vertical shortening and \( b' \) the horizontal slackening,

\[
\frac{b \times r}{\sqrt{2s - s^2}} = \frac{b - \sqrt{2s - s^2}}{b}
\]

Since \( b' = \frac{r}{1-s} \times \sqrt{2s' - s'^2} \), then \( b' \) is

\[
b' = \sqrt{\frac{2s' - s'^2}{1-s}}.
\]

Therefore the value \( m \) can be expressed as,

\[
m = \frac{b}{2(1-s) \sqrt{2s - s^2}} = \frac{b'}{2(1-s') \sqrt{2s' - s'^2}}.
\]

Under various combinations of \( s \) and \( b \) conceivable for a practical net construction, \( s' \), \( b' \) and \( m \) have been calculated from the above equations and arranged in Table 5 in the increasing order of \( m \).
Table 5. Values of $m$ under various constructions

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>0.55</th>
<th>0.50</th>
<th>0.45</th>
<th>0.55</th>
<th>0.50</th>
<th>0.45</th>
<th>0.55</th>
<th>0.50</th>
<th>0.60</th>
<th>0.55</th>
<th>0.50</th>
<th>0.60</th>
<th>0.55</th>
<th>0.60</th>
<th>0.55</th>
<th>0.60</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b'$</td>
<td>1.28</td>
<td>1.38</td>
<td>1.40</td>
<td>1.50</td>
<td>1.50</td>
<td>1.62</td>
<td>1.58</td>
<td>1.62</td>
<td>1.71</td>
<td>1.64</td>
<td>1.78</td>
<td>1.78</td>
<td>1.90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$b$</td>
<td>1.10</td>
<td>1.20</td>
<td>1.30</td>
<td>1.20</td>
<td>1.30</td>
<td>1.40</td>
<td>1.20</td>
<td>1.40</td>
<td>1.50</td>
<td>1.30</td>
<td>1.50</td>
<td>1.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S'$</td>
<td>0.19</td>
<td>0.28</td>
<td>0.35</td>
<td>0.26</td>
<td>0.34</td>
<td>0.32</td>
<td>0.39</td>
<td>0.24</td>
<td>0.36</td>
<td>0.43</td>
<td>0.30</td>
<td>0.41</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m$</td>
<td>1.37</td>
<td>1.39</td>
<td>1.40</td>
<td>1.49</td>
<td>1.50</td>
<td>1.61</td>
<td>1.62</td>
<td>1.64</td>
<td>1.73</td>
<td>1.74</td>
<td>1.77</td>
<td>1.86</td>
<td>1.91</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5. Isometric line of $m$.

From Table 5, isometric lines of $m$ in the various combination of $s(b')$ and $b(s')$ have been drawn in Fig. 5. This diagram would be of practical use for determining the essential factor, $m$, related with given values of $s(b')$ and $b(s')$ for designing a double net.

It may be worth adding here that fishing rate of double nets at sea may as well be affected by visibility of the nets, bioluminescence on them, and different resistance of meshes against current. However, as the present experiments were carried out by controlling or neglecting these factors, further experiments under uncontrolled conditions have to be performed in the future before recommending a double net to industrial use.

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Reference

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