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Original Article

Mesh selectivity of a sweeping trammel net for Japanese whiting *Sillago japonica*

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SUMMARY: To determine the mesh selectivity of a sweeping trammel net for Japanese whiting *Sillago japonica*, experimental fishing operations using three different inner net mesh lengths (27.5, 31.0 and 33.5 mm) were carried out in Tateyama Bay, Chiba Prefecture, Japan from August to November 1996 and from April to May 1997. The length mode of captured fish increased in proportion to the mesh length from 150–160 mm of the smallest mesh to 190–200 mm total length of the largest mesh. The master curve of selectivity in terms of length ratio to the mesh length (l/m) showed a wide selection range of 50% relative efficiency compared to the mesh selectivity curve of gill net. The curve had a peak at l/m of 6.3 with the selection range from 5.4 to 7.4. This suggested that the trammel net caught a large number of entangled or pocketed fish in comparison to the gilled fish due to the effect of inner net slackness. In terms of body girth ratio to mesh perimeter (G/P), the curve had a peak at G/P of 1.31, which reflected that relative efficiency of capture reached its maximum when the body girth of fish was 1.31 times that of the mesh perimeter.

KEY WORDS: **body girth, Japanese whiting, master curve, mesh selectivity, sweeping trammel net.**

INTRODUCTION

A sweeping trammel net is a typical entangling net with a sweeping process for increasing the encounter chances between fish and gear. In Japan, it is used for capturing demersal species, such as branquillos *Branchiostegus japonicus* along the coast of the Japan sea[1] and Japanese whiting *Sillago japonica* in Tokyo Bay.[2] Although this fishing gear is classified in the same category as a gill net,[3] it has a characteristic selectivity curve different from gill nets due to the differences in capture condition as well as its operation method.[4] In gill nets most captured individuals become gilled and wedged within a single-walled net, while in the trammel nets large-sized fish are caught by pocketing, which is different from the entangling occurring in a gill net.[5] It was observed that the sweeping trammel net in Tateyama Bay, Chiba Prefecture, Japan caught small Japanese whiting (< 160 mm) mainly by gilling, while medium- (160–200 mm) and large-sized fish (> 200 mm) mainly by entrapment into the pockets.[2]

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Generally, the selectivity pattern of the trammel net for fin-fish depends on the mesh size and the slackness of its inner net.[6] Some studies[4,7–12] reported that mesh selectivity curve of the gear skewed to the right side and had a wider selection range of 50% relative efficiency with the increase of slackness. Kitahara[4] was the first to report on the selectivity of sweeping trammel nets for *Branchiostegus japonicus* showing a positive skew of selectivity curve. For *Sillago japonica*, however, the selectivity of the sweeping trammel net has not yet been determined. With recent increasing needs on resource management for the sustainable coastal fisheries, the improvement of gear selectivity is of urgent importance.

The purpose of this study was to determine the mesh selectivity of the sweeping trammel net for Japanese whiting *Sillago japonica*, with the experimental fishing operation using different mesh sizes for the inner net.

MATERIALS AND METHODS

Specification of the sweeping trammel net

One set of a sweeping trammel net operating in Tateyama Bay, Chiba Prefecture, Japan usually consists of six pieces of triple-walled net (18 m long and 0.75 m deep per piece) attached with one piece of drag net (10 m long) at one end of the towing side, with a total of 118 m length (Fig. 1). For capturing Japanese whiting, the inner net of 27.5 mm mesh length with the outer net of 300 mm mesh length is currently used. Larger inner net mesh lengths of 30.0 mm and 32.5 mm of nominal sizes were employed here in order to compare the catch size distribution against the 27.5 mm nominal mesh length. Careful measurements of mesh lengths for three mesh sizes showed the variation of actual lengths against the nominal lengths in the case of the larger meshes. The actual mesh lengths of 27.5, 31.0 and 33.5 mm are discussed for further analytical procedures on mesh selectivity curve. The mesh length is defined as the stretched net mesh measuring from one center of a knot to the other.

The webbing of the nets was a nylon multifilament (i.e. PA-210 D/2 for the inner net, PA-210 D/6 for the outer net, and PA-210 D/9 for the dragging net). The hanging ratio of the outer net was 0.65 and the inner net was 0.47, while the slackness of the inner net ranged from 1.83 to 1.99. Detailed description of the experimental sweeping trammel net is presented in Table 1.

Experimental fishing operations

The experimental fishing operations were carried out in a sandy or sandy-mud fishing ground of 5–10 m depth in Tateyama Bay (Fig. 2), during two periods from August to November 1996 and from April to May 1997. Five fishing trips with 47 hauls and four trips with 34 hauls were done in 1996 and 1997, respectively.

The experimental fishing operation with a commercial boat was as follows.[2] First, the net was set on the seabed along the direction of right angle to offshore after shooting a center buoy. Next, the end of the drag net was towed with the towing rope for sweeping over the seabed around the center buoy. Finally, the net was hauled up with a small-mechanized net hauler, while the catch was removed from the mesh carefully by hand. One round of the operation required 23 min on average.

To minimize effects of the net position[2] on the catch saturation and net-piece interaction,[13] the arrangement of the different mesh nets was alternated for each fishing trip during the experimental operations. With a total of nine trips operating 81 hauls, the nets of 27.5, 31.0 and

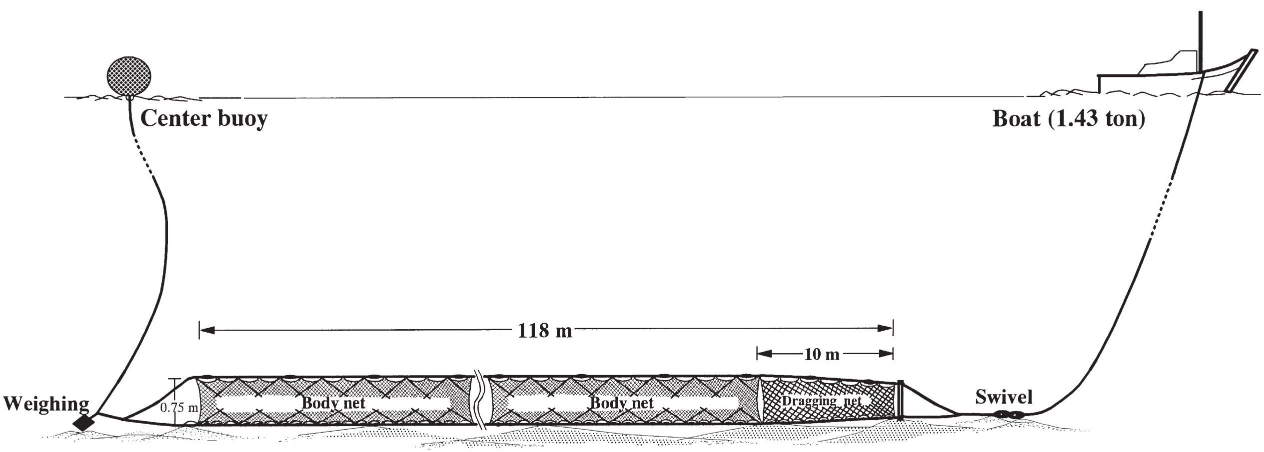

Fig. 1 Schematic diagram of sweeping trammel net operated in Tateyama Bay, Chiba Prefecture, Japan.

Table 1 Specification of an experimental sweeping trammel net used in the experiment

Net parts	Materials	Mesh length (mean ± SD mm)	Completed length Float line (m)	Completed length Sinker line (m)	Hanging ratio Float side	Hanging ratio Sinker side	Height of net (m)	Slackness
Inner net 1	Nylon 210 D/2	27.5 ± 0.13*	18.07	18.15	0.48	0.48	0.75	1.83
Inner net 2	Nylon 210 D/2	31.0 ± 0.37	18.07	18.15	0.47	0.47	0.75	1.92
Inner net 3	Nylon 210 D/2	33.5 ± 0.35	18.07	18.15	0.47	0.47	0.75	1.99
All outer nets	Nylon 210 D/6	300	18.07	18.15	0.65	0.66	0.75	
Float	Plastic 19 gf							
Sinker	Clay 6.5 g							

* The mesh size is currently used in Tateyama Bay, Chiba Prefecture, Japan for capturing Japanese whiting.

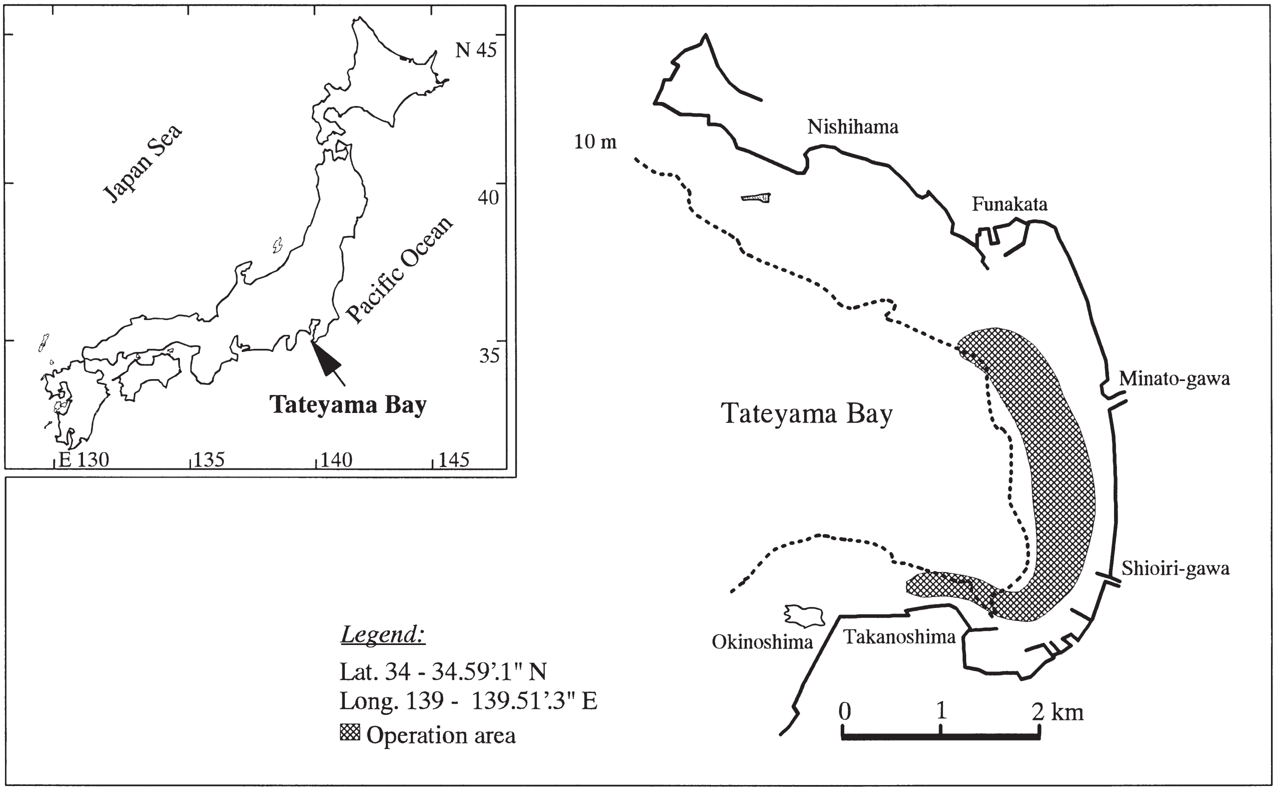

Fig. 2 Operation area for the experimental fishing operations.

33.5 mm mesh length were considered to have the same fishing power at different net positions. All the Japanese whiting caught by each different mesh length were measured in total length (*TL*) and maximum body girth to the nearest millimeter. The capture conditions of fish (i.e. snagged, gilled, entangled, and pocketed)[2] were also recorded. The maximum body girth was measured by means of encircling a polyethylene string of 1.2 mm diameter around the head part of fish just in front of the dorsal fin.

Estimation of mesh selectivity curve

The measurement data collected during the experimental fishing operations were pooled separately for each mesh length of 27.5, 31.0, and 33.5 mm, respectively. The data of total length were grouped into 10 mm intervals. Here, a single curve for selectivity (referred to as the master curve) was estimated using Kitahara's method.[4] The catch per unit effort C_{ij} of the Japanese whiting at *j*-th length class l_j ($j=1, 2, \ldots \lambda$) with *i*-th mesh length m_i can be expressed as follows:

$$C_{ij} = s(l_j/m_i)qdj \tag{1}$$

where $s(l_j/m_i)$ is the mesh selectivity, i.e. a function of the relative efficiency, and its maximum is 1, against the ratio of body length l_j to mesh length m_i, and q denotes the efficiency at the peak of mesh selectivity curve and d_j is population density of the fish at length l_j. It is assumed that q is ordinarily constant if relative efficiency is considered.

Taking logarithm for both sides of Eqn 1 gives:

$$\log C_{ij} = \log s(l_j/m_i) + \log qd_j$$
$$= \log s(l_j/m_i) + \log D_j \tag{2}$$

where $D_j = qd_j$.

The master curve of mesh selectivity $s(l_j/m_i)$ was approximated by a polynomial curve[12] expressed by the following equation:

$$s(R) = \exp\{(a_n R^n + a_{n-1}R^{n-1} + a_{n-2}R^{n-2} \ldots + a_o) - s_{\max}\} \tag{3}$$

where R is equal to l_j/m_i, and $s_{\max}$ is the maximum value of the approximated curve. Parameters, a_n, $a_{n-1}, \ldots a_o$ ($n=1, 2, \ldots \mu$) and D_j ($j=1, 2, \ldots \lambda$) are to be estimated using non-linear least square method.[14] The degree of polynomial function was determined by comparing the values of unbiased estimator for variance of errors (σ^2) between the functions of different degree as follows:

$$\sigma^2 = \theta/(\pi - p) \tag{4}$$

where $p = \mu + (\lambda - 1)$