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METHODOLOGY OF EVALUATING SELECTIVITY PERFORMANCE - TWO SELECTIVE PROCESSES OF TRAWL SORTING DEVICES: FISH ENCOUNTERING AND BEING SIEVED

by

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Abstract

The mesh selectivity of each mesh size is a basic study for size-sorting, and usually expresses the proportion retained as a function of the body length of a fish. It is however likely to depend more directly on the relationship between the girth of fish and mesh perimeter whether a fish can pass through a mesh. Selectivity curves sm(G / p) fitted to some experimental data in terms of the ratio of girth G to mesh perimeter p coincided closely for several species of different body shape. This means that geometrically similar combinations of mesh perimeter and girth have the same selectivity, and also suggests that a master curve based on girth to mesh perimeter allow estimation of the selectivity curve with girth-length relationship. The master curve analysis method is useful in particular for multi-species trawl fishery in tropical and sub-tropical areas. From the Nordmore grid fishing experiments, the grid had size-selectivity by bar-spacing in the similar as well as codend mesh selectivity. As far as grids have size-selectivity as a sieve process, sorting efficiency must depend not only on bar-spacing but also on length distributions of each species, and therefore the appropriate bar-space should be determined for sorting. The master curve analysis method can be applied to grid selectivity (proportion of fish retained by the grid). Sieving process of sorting device like grid and square mesh window panel is valid only for fishes encountering it. Another point in the sorting efficiency is the encounter probability defined as a proportion of a fish encountering the sorting device

The mesh selectivity of trawl codend is a basic study for size-sorting. There are not so much studies on mesh selectivity in tropical and sub-tropical area, because trawl fisheries which use codend of small mesh size usually catch too many species to obtain mesh selectivity of every species. This paper firstly presents as one of the solution the master curve of mesh selectivity in terms of a non-dimensional parameter (the ratio of girth to mesh perimeter) which Tokai et al.(1994) proposed on the assumption that mesh selectivity is considered as a sort of sieving process.

The selective fishing gears have been developed to separate target species from by-catch (e.g. Main and Sangster, 1985; Watson et al., 1986; Isaksen et al., 1992), of which the most successful have incorporated a type of separator panel or grid. Very little is known about the selective performance of separator panel or grids. Isaksen et al. (1992) suggested that a given bar spacing in the grid is analogous to a given mesh size in the codend. This means the grid have size-selectivity by bar-spacing just as mesh selectivity. Secondly, the master curve analysis method is extended for grid selectivity data.

Sieving process of sorting device like grid (and square mesh window panel) is valid only for fish encountering it. In the sorting devices, not all fish encounter the grid (nor the window panel). Thus, the probability that a fish encounters the grid (or panel) should be considered. Finally, a model is proposed for evaluating encounter probability from the data of a fishing experiment using cover over fish-outlet of grid (and separate covers over codend and windows).

1. MASTER CURVE OF MESH SELECTIVITY IN TERMS OF GIRTH RATIO TO MESH PERIMETER

The mesh selectivity of each mesh size usually expresses the proportion retained as a function of the body length of a fish, because it is easy and practical to measure body length and mesh size. Whether a fish can pass through a mesh is however likely to depend more directly on the relationship between the girth of fish and mesh perimeter. Proportions retained for each girth and length class of haddock in a cover-net fishing experiment tend to increase with increasing girth for a given length class, and the fish of a girth larger than the mesh perimeter cannot pass through the mesh (Tokai et al., unpublished). This proves that girth is a more severe limitations on the possibility of fish passing through the mesh than fish length.

Gear selectivity depends on various factors, such as net materials, gear construction, codend hydrodynamics, fish species, and fish size and behaviour. Concerning only with mesh perimeter of the codend, Tokai et al. (1994) considered mesh selection as a sieving process and expressed mesh selectivity (S_m) as a function of the two parameters: the mesh perimeter p and the girth G, by the following equation,

$$S_m(p, G) = S_m(G/p)$$

$$= S_m(R) \qquad (1),$$

where S_m is mesh selectivity in terms of R, the ratio of girth to mesh perimeter, i.e. $R = G/p$. This means that geometrically similar combinations of mesh perimeter and girth have the same selectivity (Fig. 1).

The proportions retained in terms of the non-dimensional parameter R revealed that a single selectivity curve accurately described the data for all mesh sizes. The proportion retained in the curve started to increase up at R = 0.5 and reached to one at R close to one. Tokai et al. (1994) derived the master curves of codend selectivity from the data of a cover-net fishing experiment in a small beam trawl for six species including dragonet of depressed body type and cardinal fish of compressed body type (Fig. 2). Tokai et al.(1989) demonstrated the master curve for two founders in terms of body depth ratio to mesh opening, instead of girth ratio to mesh perimeter (Fig. 3). The fish bodies of these eight species were of a different shape from each other, and therefore mesh selectivity versus length of these species are quite different. Nevertheless, their master curves were, on the whole, similar to each other. By substituting the girth-length equation for girth, the master curve of mesh selectivity can be obtained as a function of fish length. It suggests that a typical curve of mesh selectivity can be estimated from the master curve for any fish species. Thus, the master curve analysis method is useful in particular for multi-species trawl fishery which catch too many species in tropical and sub-tropical areas to obtain mesh selectivity of every species from fishing experiments. Tokai and Kitahara(1989) and Tokai et al.(1991) modified the master curve analysis method for animals such as shrimp of which girth is not clearly defined for mesh selectivity because of their many spines and antennae. The optimum mesh size was discussed to reduce by-catch of juvenile flounders in a shrimp beam trawl (Tokai and Kitahara, 1991).

2. SIZE SELECTIVITY OF GRID TRAWL AND ITS MASTER CURVE

This section describes grid selectivity obtained from the data of a fish-outlet cover fishing experiment of grid separator with three bar spacings (8, 10 an 15 mm) in small beam trawls and a similar approach as mentioned above is employed to investigate the selective properties of grids (Tokai et al., 1996).

2.1 Grid selectivity

In this paper grid selectivity is defined as the probability that a fish does not pass through a grid given that it has encountered the grid. Accordingly, zero percent grid selectivity indicates that all fish can pass through the grid, and grid selectivity is 100% when all fish are retained by the grid or escape through the fish outlet. Grid selectivity obtained at each length class can be also expressed as a function of length in the same way as mesh selectivity.

2.2 Master curve of grid selectivity

Assuming that grid selectivity is regarded as a sieve-process, we attempt to apply the master analysis method to grid selectivity. Instead of mesh perimeter and body girth for mesh selectivity, we consider bar spacing and cross-sectional diameter i.e. body width in fish of compressed body type or body depth in fish of depressed body type, for grid selectivity (Fig. 1). Grid selectivity S_g can be expressed as a function of the ratio of cross-sectional diameter to bar spacing as follows:

$$S_g (d, L) = S_g (R_g) \quad (2),$$

where L and d are cross sectional diameter of fish body and bar spacing of grid, and R_g = L / d. Grid selectivity with 8, 10 an 15 mm bar spacings is plotted against the non-dimensional parameter R_g of 2 shrimps, 2crabs and frog flounder(Fig. 4). This revealed that, for each species, a single selectivity curve describes accurately data of each of the grids as a master curve of grid selectivity.

As far as grids have size-selectivity by bar-spacing like a sieve process, sorting efficiency must depend not only on bar-spacing but also on the size structure of the stock of each species, and therefore the appropriate bar-space should be determined for sorting. The master curve of grid selectivity is useful for determining the appropriate bar spacing.

3. ENCOUNTER PROBABILITY MODEL

3.1 Probability of fish encountering sorting grids

Sieving process of grids mentioned above is valid only for fish encountering it. Grid selectivity master curve for southern rough shrimp were best expressed not by the logistic curves, but by the equation as follows;

$$S(R) = (1 - \delta) / \{1 + \exp(\alpha - \beta R)\} + \delta \qquad (3),$$

which allows for cases where the selection of the smaller animals does not approach zero(Tokai et al., 1996). The fact that the parameter δ is 0.152 significantly larger than zero indicates that shrimp much more slender than bar spacing escape through the fish outlet. This also means a 15.2 % loss of shrimp. The usual grid separator system consists of a grid, a fish outlet, and a funnel or flapper which guides fish and shrimp against the grid. A very high shrimp loss are reported in tests without any guiding funnel or flapper of grids (Isaksen et al., 1992) and of Georgia TEDs (Renaud et al., 1993). In this regard, we can consider $1-\delta$ as a measure of the probability of fish encountering the grid and as such may be used to quantify the effectiveness of the guiding funnel or flapper.

3.2 Probability of fish encountering square mesh window panel

A model is proposed for evaluating the retention probabilities of a square mesh window alone and of the whole codend and square mesh window together (Tokai et al., 1996; Commission of the European Communities Directorate General of Fisheries, 1996). The data was collected during a fishing experiment using separate covers over codend and window.

Because several underwater TV observations of fish behavior around a window show that not all fish encounter the square mesh window, the probability that a fish encounters the window can be described as an encounter probability, p_w. Thus, the retention probability of the window, $r_w(l)$ is,

$$r_w(l) = \{ p_w N(l) - n_w(l) \} / p_w N(l) \qquad (4),$$

where $N(l)$ and $n_w(l)$ are the number of fish of length l that enter the gear and that escape through the window, respectively. Overall selectivity of the codend with the window $r(l)$ is described as:

$$r(l) = \{ 1 - p_w + p_w r_w(l) \} r_c(l) \qquad (5),$$

where rC(l) is the codend selectivity for fish of length l. This equation means that the overall selectivity of the codend with the window is specified by the two retention probabilities and the encounter probability. Either fish retained by the window panel or having avoided the window panel will enter the codend. Using a logistic models for $r_w(l)$, proportion of fish entering the codend to the total fish is expressed as

$$n_w(l) / N(l) = p_w(l)\, r_w(l) + 1 - p_w(l)$$

$$= p_w(l) / [\, 1 + \exp(\alpha - \beta l\,)] + 1 - p_w(l). \qquad (6),$$

which is the same form as equation (3). The parameters of logistic equation α and β and encounter probability p_w are determined from the data in the covered window and codend selectivity experiment. The estimated values of encounter probability for each haul are 0.26 - 0.76, which is not so high as expected.

Encounter probability and size-selectivity as a sieve like effect in sorting devices should be evaluated for better sorting.

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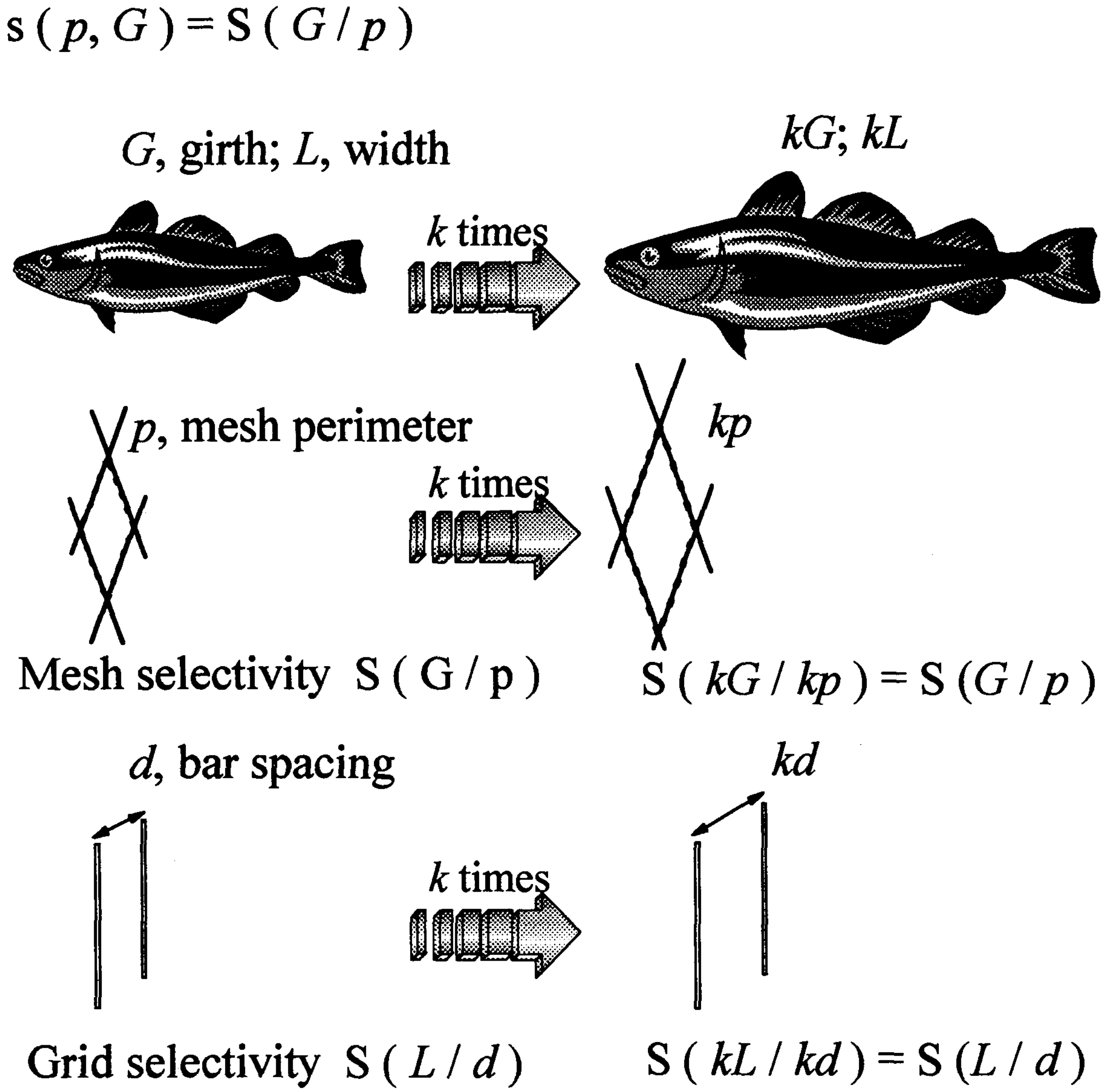


Fig.1. The combination of mesh perimeter and body girth in mesh selectivity (and bar-spacing and body width for grid selectivity) have the same selectivity.

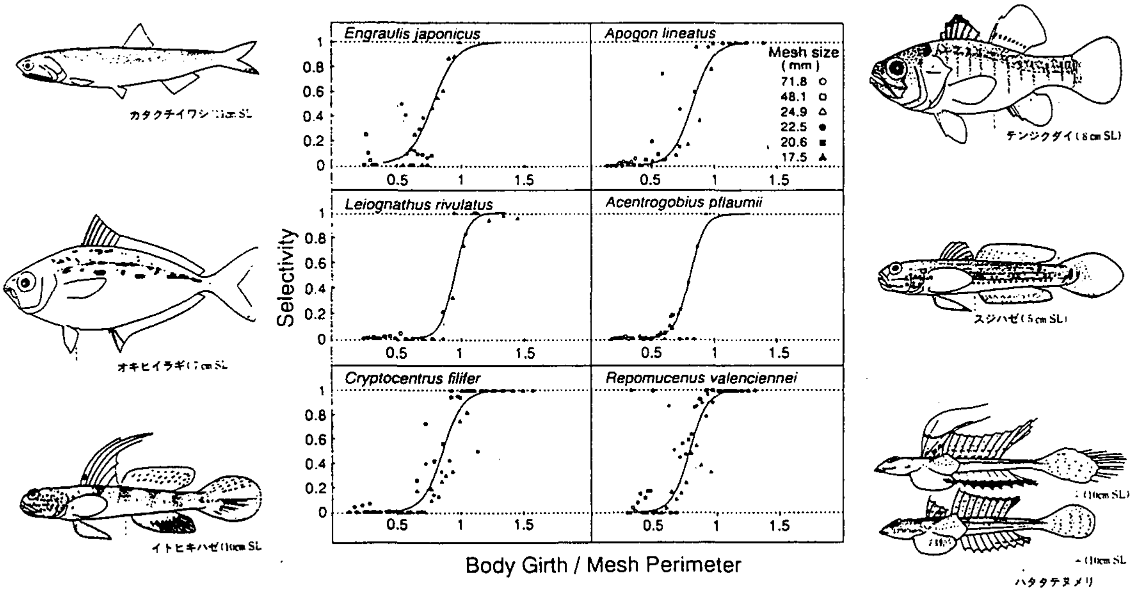


Fig. 2. Master curves of mesh selectivity in terms of girth ratio to mesh perimeter for six species (Tokai et al., 1994).

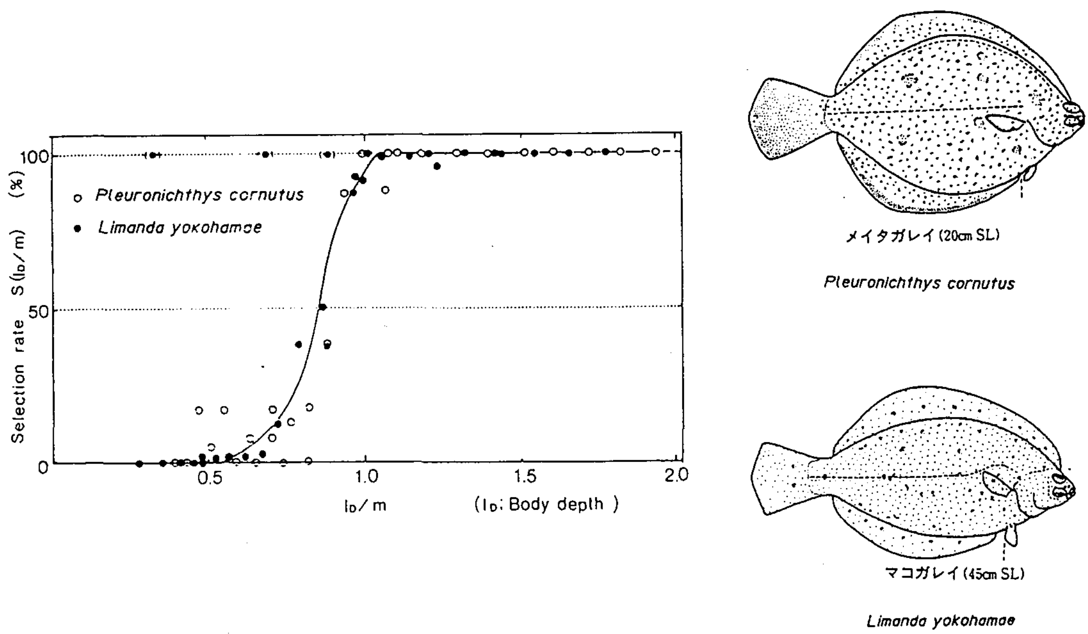


Fig. 3. Master curve of mesh selectivity for flounders in terms of body depth ratio to mesh opening, almost the same as girth ratio to mesh perimeter (Tokai et al., 1989).

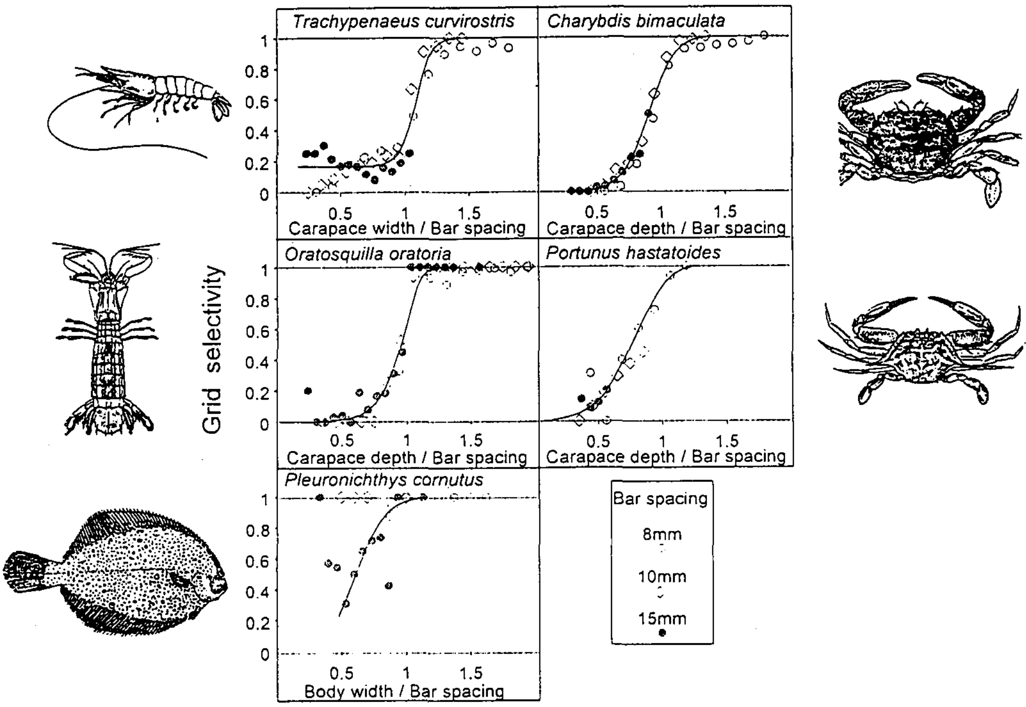
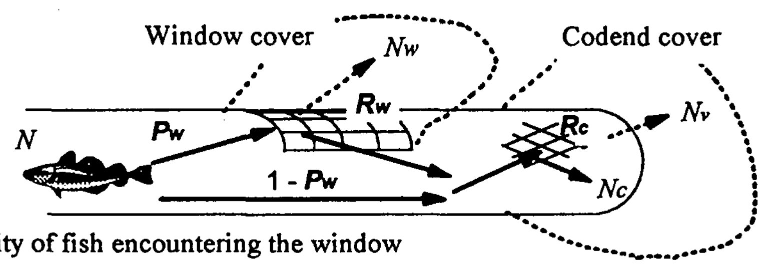
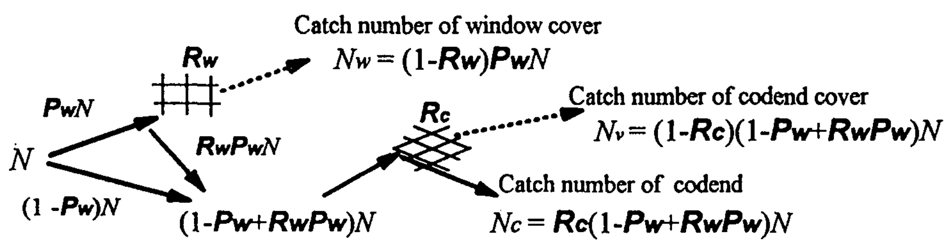


Fig.4. Master curve of grid selectivity for each species(Tokai et al., 1996).



Pw: Probability of fish encountering the window

Rw, *Rc*: Retention probability of the window, the codend, respectively



$$\text{Overall selectivity: } R = N_c / N = (1 - P_w + R_w P_w) R_c$$

Fig. 5. Encounter probability model for evaluating selectivity of codend with square mesh window in the cod-extension.