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Mesh Selectivity of the Cod-end of a Small Trawl Net for Two Peruvian Drums (*Paralonchurus peruanus* and *Sciaena deliciosa*) from the Callao Sea Zone, Peru

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Mesh selectivity experiments of the cod-end of a small trawl net were carried out in the coastal fishing zone off Callao, Peru. The studies were conducted using two different mesh sizes, 2" and 3", at the cod-end. The cod-end was entirely coverd with a 1 1/4" mesh net. Target fishes for the present study were two Peruvian drums (*Paralonchurus peruanus* and *Sciaena deliciosa*), representing 78% of the total weight caught. The body shape of these species is slightly different.

Nonsymmetrical and symmetrical curves were applied for mesh selectivity of the cod-end. Three selectivity factors were used: 1) mean selection length (L_c, cm), 2) selection range (*S.R*, cm), and 3) selection factor (*S.F*, nondimensional).

The *S.F* values were obtained as: 1) nonsymmetrical curve: for Coco; 3.21 in 3" mesh and 3.53 in 2" mesh; and for Lorna 3.30 in 3" mesh and 3.51 in 2" mesh. 2) symmetrical curve: for Coco; 3.21 in 3" mesh and 3.50 in 2" mesh, and for Lorna; 3.33 in 3" mesh and 3.53 in 2" mesh.

The selectivity factors were compared between the nonsymmetrical and symmetrical curves. The results obtained were: 1) meam selection lengths ($L_c = L_{0.50}$) showed approximately the same values for both the nonsymmetrical and symmetrical curves, 2) the differences in the *S.R* value between the 3" and 2" meshes for the nonsymmetrical curve were shorter than those for the symmetrical curve, and 3) the *S.F* values between the 3" and 2" meshes in both the nonsymmetrical and symmetrical curves showed approximately the same pair values.

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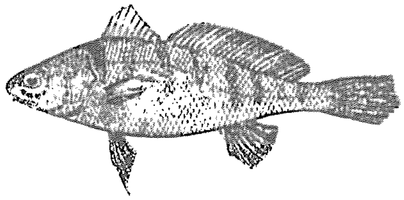
1 Introduction

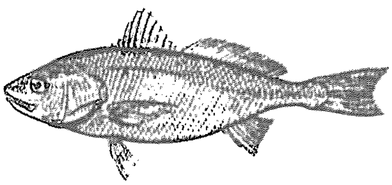
One of the international interests in fishing gear is to develop selective gear for a specific fish size and species. Though these interests are stimulated by an adequate management of fishery resources, the traditional small trawl gear in Peru can not be modified at this moment to a selective gear due to limited knowledge of the gear and existing ichthyofauna.

Many mesh selectivity studies can be noted around the world, but in relation with the trawl selection and selection curves fitted to the data from each haul we can be cited the mathematical models presented by Ricker, W. (1979) and Sparre *et al.* (1989) who developed sigmoid curves to describe the selection ogive.

Using a small trawl net, an experiments of cod-end mesh selectivity were conducted in the coastal fishing zone off Callao, Peru. Mesh selectivity studies of the cod-end will contribute not only to gear improvement but also to resource evaluation. For example, the selection mean length is related to the exploited mean size at the first capture which is important for the management of many fisheries.



(a) Peruvian drum
***Paralonchurus peruanus*, Coco**



(b) Peruvian drum
***Sciaena deliciosa*, Lorna**

Fig. 1. Body shape of Peruvian drums (by N. Chirichigno, 1974).

Two Peruvian drums in Fig. 1 (*Paralonchurus peruanus*, Coco in Spanish and *Sciaena deliciosa*, Lorna in Spanish; hereafter the Spanish names are used in text), which were the main species caught, were objective fishes for mesh selectivity. Normally these species are caught by artisanal fishermen along the Peruvian coast in the central and northern zones throughout the year.

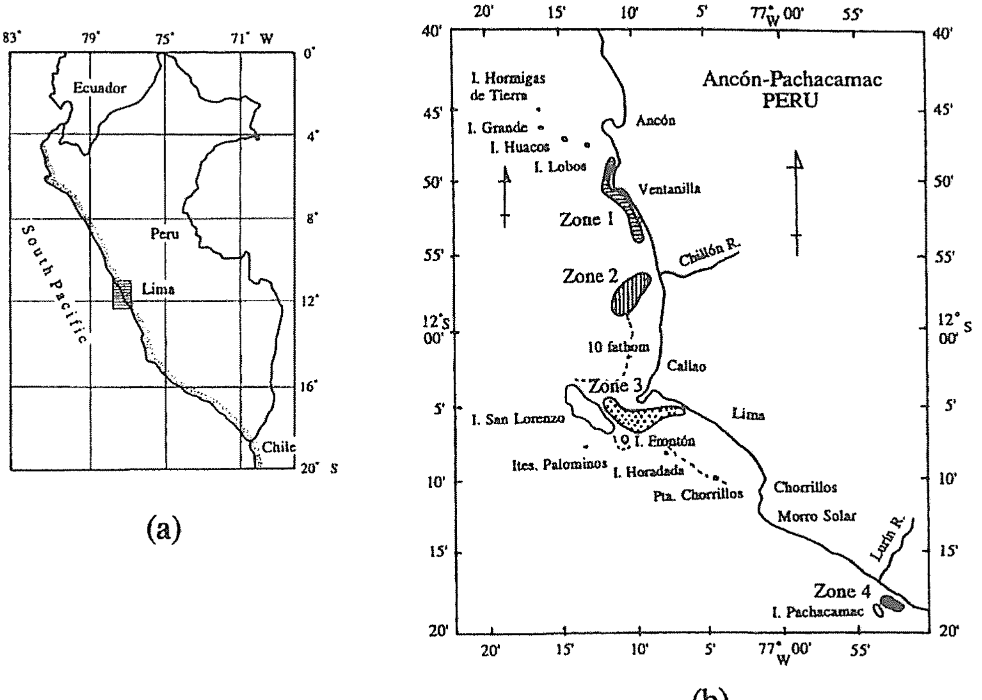
The objective of this paper is to determine the mesh selectivity of the cod-end of a small trawl net for these species. The results will help to design appropriate mesh size of a cod-end based on the different mesh selectivity curves assumed by the symmetric and nonsymmetric curves.

2 Materials and Methods

2.1 Sea zones, fishing boat and trawl net

The experiments were conducted between July, 1989 and June, 1990 in the Callao sea zone off the central coast of Peru. Four study zones of experiments were selected that depended on the sea bottom conditions for trawling (Fig. 2).

The dimensional data of a wooden coastal fishing boat used for the experiment are as follows: overall length, 10.97 m; breadth, 3.96 m; depth, 1.52 m; fish holding capacity, 6 tons; and main engine horse power, 56 ps. The small bottom trawl net used was constructed of four panels of nylon twine and English knot netting (Fig. 3). The trawl doors were rectangular (0.9 m x 0.5 m) and made of wood plank and iron shoes. The trawl net was designed by applying the recommendations



(a)

(b)

Fig. 2. Location of sea zone.

given by Koyama (1974) and Nomura (1975). The mesh size of the wings, bating and a part of the entrance of the cod-end used a 1 1/2" (=3.8 cm) mesh net and that of the belly used 7/8"(=2.2 cm) mesh.

The covered net method (Pope *et al.*, 1983 and Tokai *et al.*, 1989) was applied to examine the mesh selectivity of the cod-end. The experiments were carried out using a cod-end with two different mesh sizes, 2" (=5.1 cm) and 3" (=7.6 cm), and the outside of the cod-end was totally covered with a small mesh net of 1 1/4" (=3.2 cm) size. Figure 4 shows the detailed cod-end supported with the metallic hoops. The trawling duration and speed were about 60 minutes and 1.5 knots, respectively, for each haul.

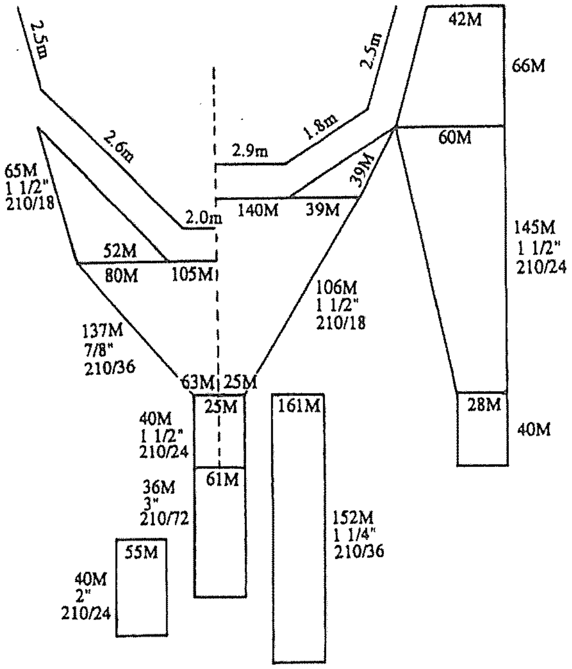


Fig. 3. Drawing of small trawl net.

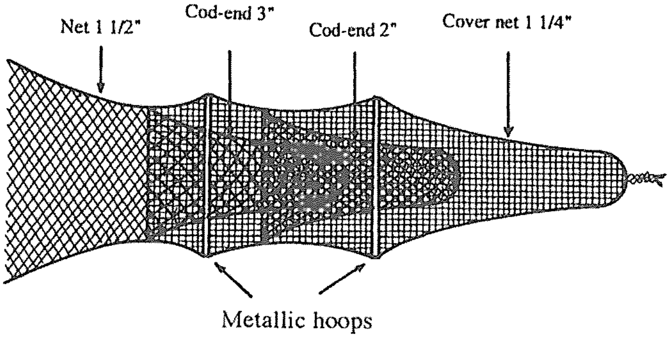


Fig. 4. Rigging of covered cod-end.

2.2 Mesh selectivity of cod-end

2.2.1 Product of calculation data and mean total length

Classifying by the species, number of fish retained; ${}_{3}N_i$ for 3" mesh, ${}_{2}N_j$ for 2" mesh, and ${}_{1\,1/4}N_k$ for 1 1/4" mesh. The fraction retained for the i th length of fish, ${}_{3}y_i$ for 3" mesh, and that for the i th and j th length of fish, ${}_{2}y_{i,j}$ for 2" mesh, were calculated:

$$ {}_{3}y_i = {}_{3}N_i / {}_{t}N_{i,j,k} \qquad (0 \leqq {}_{3}y_i \leqq 1) \qquad (1) $$

$$ {}_{2}y_{i,j} = {}_{2}N_{i,j} / {}_{t}N_{i,j,k} \qquad (0 \leqq {}_{2}y_{i,j} \leqq 1) \qquad (2) $$

$$ (i=0, 1, 2, \cdots, l, j=0, 1, 2, \cdots, m, k=0, 1, 2, \cdots, n) $$

$$ (j=i+p, k=j+q, \text{ and } p \text{ and } q=\text{constants}) $$

where ${}_{2}N_{i,j} = {}_{3}N_i + {}_{2}N_j$ for 2" mesh (3" mesh+2" mesh) and ${}_{t}N_{i,j,k} = {}_{3}N_i + {}_{2}N_j + {}_{1\,1/4}N_k$ for total (3" mesh+2" mesh+1 1/4" cover net). When $i=0$, ${}_{3}y_0=0$, and if $i=l$, ${}_{3}y_l=1$ in Eq.(1), also, when $j=0$, ${}_{2}y_{-a,0}=0$, and if $j=m$, ${}_{2}y_{m-a,m}=1$ in Eq.(2) were obtained respectively. The values obtained from Eqs.(1) and (2) were used as the data for mesh selectivity.

Total length (L in Fig. 5) in each specimen was measured. From the distribution of the total length, the mean total lengths, $L(3)$, $L(2)$ and $L(1\ 1/4)$ corresponding to the 3", 2" and 1 1/4" mesh, respectively, were calculated from:

$$ L(3) = \Sigma ({}_{3}L_i \cdot {}_{3}N_i) / \Sigma {}_{3}N_i \qquad (3) $$

$$ L(2) = \Sigma ({}_{2}L_j \cdot {}_{2}N_{i,j}) / \Sigma {}_{2}N_{i,j} \qquad (4) $$

$$ L(1\ 1/4) = \Sigma ({}_{1\,1/4}L_k \cdot {}_{t}N_{i,j,k}) / \Sigma {}_{t}N_{i,j,k} \qquad (5) $$

2.2.2 Mesh selectivity factors

2.2.2.1 Nonsymmetrical curve

By applying the Trapezoidal rule, the mean selection length L_c (in cm) is determined from the $L_{0.50}$, "the length at the mid-point of the area of 50% fraction retained of fish", to define the selection factor ($S.F$). Also, the selection lengths $L_{0.25}$ and $L_{0.75}$, the lengths at the mid-point of the area of 25% and 75% fraction retained of fish, respectively, were calculated to determine the selection range ($S.R$). In Appendix Fig. 1, the $L_c (=L_{0.50})$, $L_{0.25}$, and $L_{0.75}$ corresponding to Appendix Eqs.(A-1), (A-3) and (A-4) are rewritten, respectively, as;

$$ L_c = L_{0.50} = L_n - \int_a^b y(l)\,dl \qquad (6\text{-}1) $$

$$ L_{0.25} = L_c - (1/y_c) \int_a^c y(l)\,dl \qquad (6\text{-}2) $$

$$ L_{0.75} = L_n - \int_c^b y(l)\,dl \qquad (6\text{-}3) $$

where $y(l)$ is the fraction retained with a function of the total length of fish, $\int y(l)dl$ is the area of a mesh selectivity curve, and L_n (in cm) is the selection length of the 100% fraction retained of fish.

The Trapezoidal rule is applied for determining the areas $\int y(l)dl$ in Eqs.(6-1), (6-2) and (6-3).

Since the total length of fish was classified every 1 cm in this study, $h=1$ in the Appendix Eqs. and Appendix Fig. 2. Then in Appendix Fig. 1-(a) $\int y(l)dl$ in Eq.(6-1) is represented by

$$\int_a^b y(l)dl = (1/2)y_0 + y_1 + y_2 + \cdots\cdots + y_{n-1} + (1/2)y_n \qquad (7\text{-}1)$$

Eqs.(6-2) and (6-3) (Appendix Figs. 1-(b) and 2) are presented, respectively, as

$$\int_c^b y(l)dl = (1/2)y_0 + y_1 + y_2 + \cdots\cdots + y_{m-2} + (1/2)y_{m-1}(1+h') + (1/2)y_c h' \qquad (7\text{-}2)$$

$$\int_c^b y(l)dl = (1/2)y_c(1-h') + (1/2)y_m(2-h') + y_{m+1} + y_{m+2} \cdots\cdots + y_{n-1} + (1/2)y_n \qquad (7\text{-}3)$$

where $h' = L_c - l_{m-1}$ (Appendix Fig. 2), and y_0, $y_1, \cdots, y_c, \cdots, y_n$ are the fraction retained corresponding to $l_0, l_1, \cdots, L_c, \cdots, l_n$, respectively.

In Eqs.(6-2), (6-3), (7-2) and (7-3) the mean fraction retained of fish y_c should be calculated qutting $h=1$ in Appendix Eq.(A-8)

$$y_c = h'y_m - (h'-1)y_{m-1} \qquad (8)$$

The selection range ($S.R$, in cm) is calculated from the $L_{0.25}$ and $L_{0.75}$ obtained in Eqs. (6-2) and (6-3).

$$S.R = L_{0.75} - L_{0.25} \qquad (9)$$

The selection factor ($S.F$, nondimensional) is defined using L_c obtained from Eq.(6-1):

$$S.F = L_c/(m_2 \text{ or } m_3) \qquad (10)$$

where m_2 and m_3 are the mesh sizes in centimeters corresponding to the 2" and 3" mesh sizes, respectively.

2.2.2.2 Symmetrical curve:

The simplest method is to use the symmetrical models using the $L_{0.50}$, $L_{0.25}$ and $L_{0.75}$.

The fraction retained $y(l)$ is determined by applying the Logistic curve in this study:

$$y(l) = 1/\{1 + e^{(-al+b)}\} \qquad (11)$$

where a and b are constants. These constants are mathematically defined by each species and mesh size.

$$L_c = b/a \qquad (12)$$

The $S.R$ is determined by substituting the values $L_{0.25}$ and $L_{0.75}$ into Eq.(9)

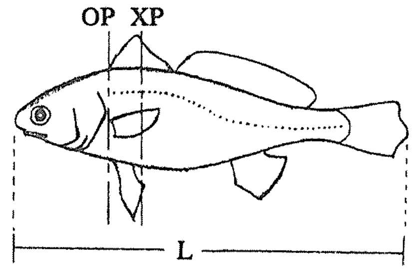
$$L_{0.25} = (b - \ln 3)/a \qquad (13)$$

$$L_{0.75} = (b + \ln 3)/a \qquad (14)$$

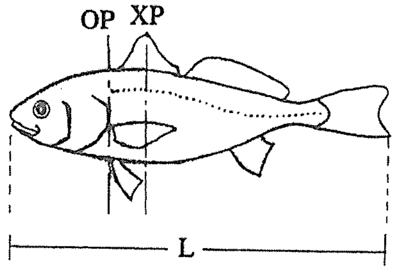
Therefore

$$S.R = (2 \cdot \ln 3)/a \qquad (15)$$

The $S.F$ is calculated by substituting the L_c obtained from Eq.(12) into Eq.(10).



(a) Peruvian drum, *Paralonchurus peruanus*, Coco



(b) Peruvian drum, *Sciaena deliciosa*, Lorna

Fig. 5. Measurement positions for Peruvian drums. *L*: Total length (cm), *OP*: Operculum perimeter (cm), *XP*: Maximum perimeter (cm).

2.3 Body measurement of species

The total weight (*W*, g), the opercular perimeter (*OP*, cm) and the maximum perimeter (*XP*, cm), the total length (*L*, cm) were measured to be characterised the body shape of species for mesh size (*MS*, cm) of cod-end. Figure 5 shows the measurement positions of *OP*, *XP* and *L*.

3 Results and Discussion

3.1 Fish and catch in the studied area

Table 1 shows the valid hauls, total catch, fishing depth and main species caught. From the 108 hauls carried out, 74 hauls were valid crresponding to a 68.5% of total haul and a 940 kg of total catch. The main species caught were Coco (1575 specimens) and Lorna (945 specimens). Species percentages for the total catch weight are the 66% (618 kg) of Coco and the 12% (115 kg) of Lorna.

The total catch and catch per valid haul vary with the sea zones studied (Fig. 2, Table 1 and Fig. 2-(b)); zone 4 showed the highest catch with 22.9 kg/haul while 4.6 kg/haul for zone 1 with the lowest catch. The fishing depth for all zone ranged between 5 and 15 m. Coco was mainly caught in zones 3 and 4 and Lorna in zones 1 and 2.

Table 1. Results obtained adout experiments and species caught in the sea zones studied

Zone	1	2	3	4
Total hauls	16	7	64	21
Valid hauls (v. l. haul)	10	3	45	16
Valid rate of haul (%)	62. 5	42. 9	70. 3	76. 2
Total catch (kg)	46. 0	26. 9	278. 3	366. 0
Catch/v. l. haul (kg)	4. 6	9. 0	6. 2	22. 9
Fishing depth (m)	5-15	10-15	5-15	10-15
	Proportion of the weight (%)			
Drums (*Paralonchurus peruanus*, Coco)			45	62
Drums (*Sciaena deliciosa*, Lorna)	85	92	8	8
Ratfish (*Callorhinchus callorynchus*, Pejegallo)			20	3
Sea-catfishes (*Galeichthys peruvianus*, Bagre)			9	13
Kingfish (*Menticirrhus ophicephalus*, Mismis)	14			3
Grunt (*Isacia conceptionis*, Cabinza)		7	6	
Rays (Rajidae, Rayas)				8

3.2 Mesh selectivity of cod-end

The selection factors, L_c, $S.R$ and $S.F$, indicate the mesh selective properties of the cod-end.

Figure 6-(a) and (b) show the frequency of the length composition for each species and mesh size. From the distributions of the total length of fish retained, the mean total length for each species was calculated using the weighted mean (Eqs.(3), (4), and (5)). An unimodal distribution was observed and Coco had a wide distribution range between 10 and 41 cm with a maximum frequency at 18 cm. Compared with Coco, Lorna had a narrower distribution range between 13 and 30 cm with a maximum frequency at 17 cm. The mean length for each species and mesh size of the cod-ends and cover net were as follows; for Coco; 27.0 cm in 3" mesh, 21.6 cm in 2" mesh, 20.6 cm in 1 1/4" cover net, and for Lorna; 24.2 cm in 3" mesh, 20.5 cm in 2" mesh, 18.7 cm in 1 1/4" cover net.

Sigmoid curves can be divided into two types: 1) a nonsymmetrical curve, and 2) a symmetrical curve. In general a selectivity curve of the cod-end is presented by a nonsymmetrical curve, because the curve does not show the normal distribution as is found in Figs. 6-(a) and (b).

For determining the nonsymmetrical curve, the Trapezoidal rule (Appendix) was introduced to calculate the areas. Using this rule, the $L_{0.25}$, $L_{0.50}$ and $L_{0.75}$ were calculated.

The nonsymmetrical mesh selectivity curves are shown in the upper part of Figs. 7-(a) and 7-(b) drawn a line passing through the calculated data for each species and mesh size. A visual comparison of these curves shows quasi-symmetrical shape suggesting a significant coincidence in the symmetrical curves (lower part of Figs. 7-(a) and 7-(b)), except for the case of Lorna for the 3" mesh. This exception may be due to few number of fish retained in the cod-end (upper part of Fig. 6-(b)).

On the other hand, approximating the symmetrical curve, a Logistic model was adopted to calculate the lengths. Table 2 shows the coefficients of the Logistic curve (Eq.(11)) for each species and mesh size.

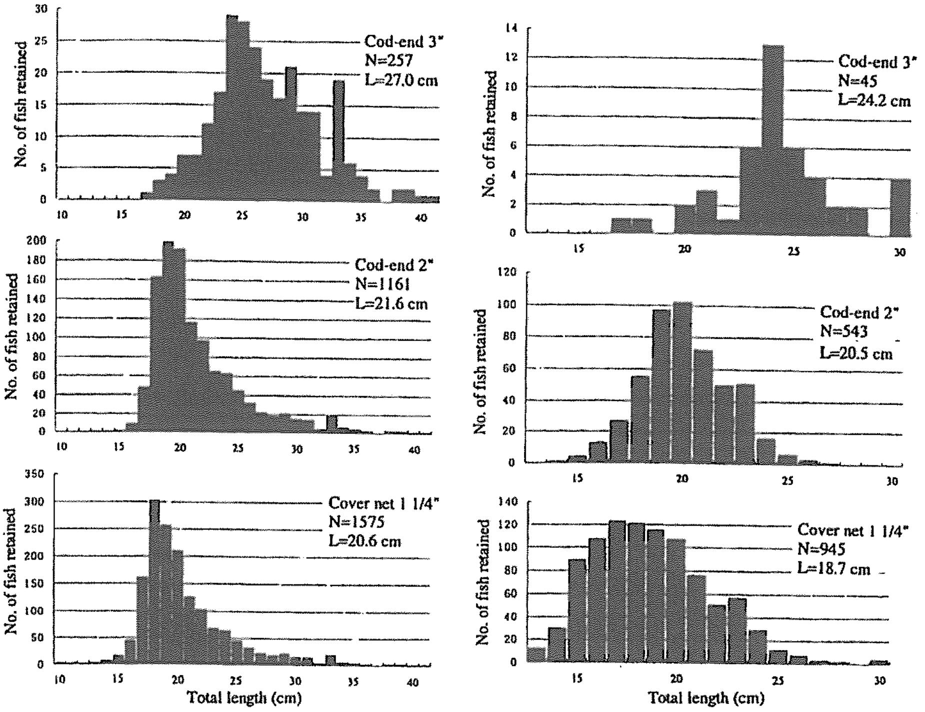
The determined coefficients for all mesh sizes based on the Logistic model fit well on the observed data and showed a good precision ($R^2=0.929$ to 0.996 in Table 2) for the fraction retained as a function of fish length. Consequently, their coefficients can be used for estimating the selection lengths for $L_{0.25}$, $L_{0.50}$, and $L_{0.75}$. Using the model, the $L_{0.25}$, $L_{0.50}$ and $L_{0.75}$ were calculated. From these data, the selectivity curves for the 2" and 3" mesh were obtained for each species.

Table 3 shows the mesh selectivity factors obtained using the nonsymmetrical and symmetrical curves for both species and mesh size. The selectivity factors were as follows:

1) The mean selection lengths (L_c) showed approximately the same values both in the nonsymmetrical and symmetrical curves for each species and mesh size.

2) The selection range ($S.R$) indicates a sharpness of selection which denotes a sharpness of the curve slopes. The $S.R$ values for the nonsymmetrical curve were much shorter than those for the symmetrical curve except for the case of the 2" mesh for Lorna. The differences in the $S.R$ values between the 3" and 2" meshes for the nonsymmetrical curve were shorter than those for the symmetrical curve. The difference in $S.R$ naturally occurred, because the definition of the selection length for nonsymmetrical curve is different from that for the symmetrical one.

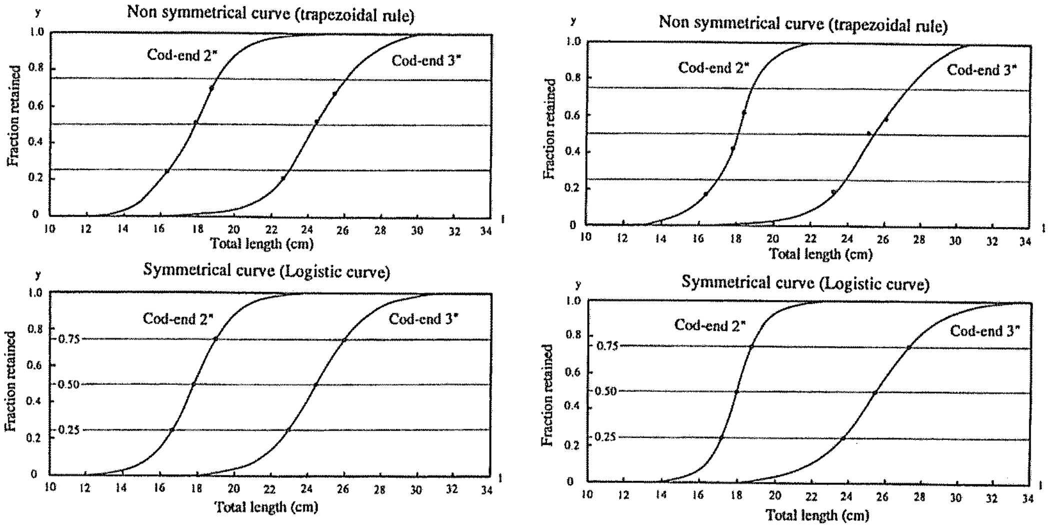
3) The selection factors ($S.F$) were obtained for two different curves:(1) the nonsymmetrical curve: for Coco; 3.21 in 3" mesh and 3.53 in 2" mesh; and for Lorna; 3.30 in 3" mesh and



(a) Peruvian drum
***Paralonchurus peruanus*, Coco**

(b) Peruvian drum
***Sciaena deliciosa*, Loma**

Fig. 6. Number of fish retained for two species of Peruvian drums and cod-end mesh size.



(a) Peruvian drum
***Paralonchurus peruanus*, Coco**

(b) Peruvian drum
***Sciaena deliciosa*, Loma**

Fig. 7. Selection curves obtained for two species of Peruvian drums and cod-end mesh size.
These curves are separated by the methods used: nonsymmetrical curve and symmetrical curve.

Table 2. Coefficients of Logistic curve: $y(l)=1/\{1+e^{-(al+b)}\}$

Species	Mesh size		Coefficients		Coef. of determination
Peruvian drums	inch	cm	a	b	R^2
Coco	3	7.62	0.718	17.57	0.996
	2	5.08	0.914	16.25	0.994
Lorna	3	7.62	0.610	15.48	0.929
	2	5.08	1.339	24.03	0.992

Table 3. Comparisons of mesh selectivity factors of cod-end between the nonsymmetrical and symmetrical curves for Peruvian drums

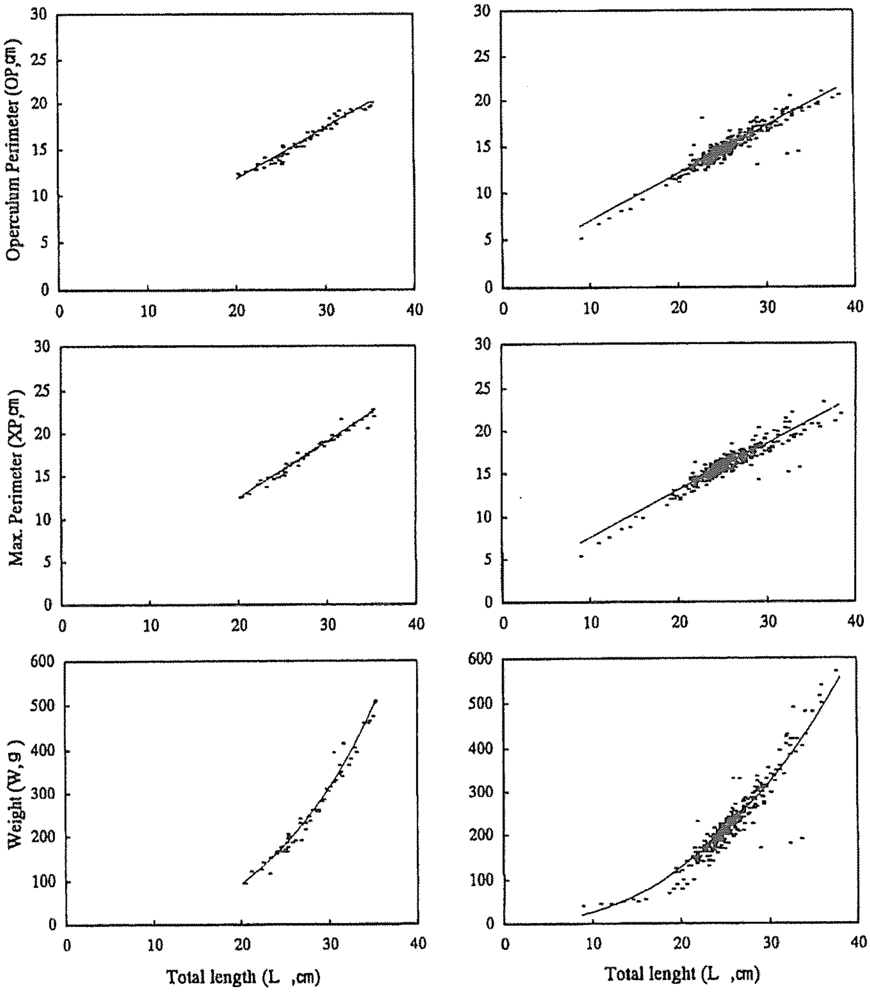
Species: Peruvian drums	Coco		Lorna	
Mesh size (inch)	3	2	3	2
(cm)	7.62	5.08	7.62	5.08
Nonsymmetrical curve defined by area (applied Trapezoidal rule)				
Mean selection length at mid-point of 50% area ($Lo_{0.50}$, cm)	24.48	17.91	25.14	17.81
Selection length at mid-point of 75% area ($Lo_{0.75}$, cm)	25.43	18.69	26.12	18.38
Selection length at mid-point of 25% area ($Lo_{0.25}$, cm)	22.70	16.40	23.24	16.43
Selection range ($S.R$, cm)	2.73	2.29	2.88	1.95
Selection factor ($S.F$)	3.21	3.53	3.30	3.51
Symmetrical curve defined by length (applied Logistic curve)				
Mean selection length at mid-point of 50% length ($Lo_{0.50}$, cm)	24.47	17.78	25.38	17.94
Selection length at mid-point of 75% length ($Lo_{0.75}$, cm)	26.00	18.98	27.18	18.74
Selection length at mid-point of 25% length ($Lo_{0.25}$, cm)	22.94	16.58	23.58	17.12
Selection range ($S.R$, cm)	3.06	2.40	3.60	1.62
Selection factor ($S.F$)	3.21	3.50	3.33	3.53

Paralonchurus peruanus, Coco and *Sciaena deliciosa*, Lorna

3.51 in 2" mesh.(2) the symmetrical curve: for Coco; 3.21 in 3" mesh and 3.50 in 2" mesh, and for Lorna; 3.33 in 3" mesh and 3.53 in 2" mesh. In case of the same curve and mesh size, the results indicate that the *S.F* were similar for Coco and Lorna. In the nonsymmetrical and symmetrical curves, the *S.F* values for each species and mesh size coincided and the *S.F* values were low (3.21 to 3.33) for the 3" mesh compared with that for the 2" mesh (3.50 to 3.53). This may be due to the use of thick twine for the 3" mesh {210 d/72 (210 d corresponding to 23 tex) in Fig. 3}, which causes rigidity and impedes a good selection or escape of fishes. According to Pope *et al.* (1983), the selection factor varied between 2.0 and 5.0 in the case of North Atlantic trawl catch. Variation of Coco and Lorna lie in a similar range.

3.3 Body characteristics of Coco and Lorna

Figure 8 shows the body characteristics of Coco and Lorna; the operculum perimeter (*OP*), the maximum perimeter (*XP*) and the weight (*W*) are plotted against the total length (*L*). From Table 3 and Fig. 7, both species presented a clear difference in the shape of the mesh selectivity curve between the 3" mesh and the 2" one, not only for the symmetrical



(a) Peruvian drum
***Paralonchurus peruanus*, Coco**

(b) Peruvian drum
***Sciaena deliciosa*, Lorna**

Fig. 8. Body characteristics of Peruvian drums.

Table 4. Body characteristics of main species caught

	Coco	Lorna
No. of specimens	56	340
Mean operculum perimeter (OP, cm)	16.1	14.8
Mean maximum perimeter (XP, cm)	17.7	16.0
Condition factor (a)	0.013	0.064
Exponent (n) in relation of total length (L) · weight (W)	2.968	2.515

$W = a\ L^{n}$

curve but also for the nonsymmetrical one. The difference could be explained by the large *S.R.* for the 3" mesh, which consequently resulted in an easy escape of fish as compared with 2" mesh.

Since the efficiency of the fish retention depends on the fish body shape, the difference in the efficiency for the 3" mesh between Coco and Lorna were compared. The body characteristics of Coco and Lorna in the case of 3" mesh size are given in Table 4. Coco showed a large transversal area due to the exponent parameter in the relation of length-weight, $n=2.968$, which is almost cubic ($n=3$). Lorna's body is a flatter (or slender) shape as the transversal area is small ($n=2.515$).

On the other hand, a cod-end's mesh opening can never keep a square shape, therefore, Coco can be retained more easily as compared with Lorna. These facts could be theoretically verified using the operculum, maximum, and mesh perimeters. The relationships between the mesh perimeter ($2\times MS$) and the *OP* and *XP* were obtained in the case of the 3" mesh: for Coco, showing lower values than the unit value ($=1$) with $(2\times MS)/OP=0.95$ and $(2\times MS)/XP=0.86$, and for Lorna, showing almost the same unit value with $(2\times MS)/OP=1.03$ and $(2\times MS)/XP=0.95$. Consequently, the efficiency of the fish retention of a mesh for Coco is higher than that of Lorna. In the same way, this fact could be explained using the number of retained fish as presented in Fig. 6. Signifying the number of fish retained for the 3" mesh as ${}_3N_i$ and that for the total as ${}_tN_{i,j,k}$: for Coco, the ${}_3N_i=257$ and ${}_tN_{i,j,k}=1575$, and for Lorna, ${}_3N_i=45$ and ${}_tN_{i,j,k}=945$ (Fig. 6). The proportion of the fraction retained of fish for the 3" mesh (${}_3y_i$ x100) for Coco represented 16.3%, and that for Lorna showed only 4.8%. Therefore, Coco is more difficult to escape from the 3" mesh than Lorna, because the fraction for Coco is about a three times bigger (16.3/4.8=3.4) than that for Lorna.

For Lorna and the 2" mesh, the mesh selection length $L_c=17.81$ cm for the nonsymmetrical curve and $L_c=17.94$ cm for the symmetrical curve have almost the same value with 17.5 cm. This value was the first sexual mature length (or biological minimum size) presented by Chirichigno and Sandoval in 1962 (internal information, not published). On the other hand, the 3" mesh for Lorna was given with the Peruvian legal minimum mesh size of the 3.1" mesh restricted by Fishery Ministry in 1973 for drift nets of Lorna along the Peruvian coast.

Some problems have been presented as a result of this research:

1) The slope of a selectivity curve, in principle, has to be the same between the 3" and 2" mesh. When the number of samples is small as shown in the 3" mesh of Lorna, the slope is different for the two mesh sizes (Fig. 7-(b)). One is due to a difference in data accuracy. Therefore, the sample number has to be sufficiently collected for analysis.

2) The twine used for the 3" mesh (210 d/72) is much larger than that for the 2" mesh (210 d/24). If the same twine (210 d/24) had been used for both meshes, the number of fish retained in the 3" mesh would be increased.

3) A defect in the covered net method is the blocking of escaping fish from the opening meshes when the meshes of the cod-end were closed due to a large number of fish or seaweeds.

4) Fish retaining depends on the body shape of the fish. Therefore, mesh selectivity of the cod-end has to be studied and compared in fish with a similar body shape such as Coco and Lorna, respectively.

5) Biological studies of Coco and Lorna have to be conducted, which are related to reproduc-

tion such as sexual maturity and the first spawning, etc., because the selectivity of the cod-end depends on these.

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Appendix

Trapezoidal rule used for calculating the area in the nonsymmetrical curve The following relationship can be established

from Appendix Fig. 1-(a)

$$(L_n - L_c) \cdot 1.0 = \int_a^b y(l)\,dl \qquad \text{(A-1)}$$

Applying the Trapezoidal rule to Eq.(A-1)

$$\int_a^b y(l)\,dl = \{(1/2)y_0 + y_1 + y_2 + \cdots\cdots + y_{n-1} + (1/2)y_n\}\,h \qquad \text{(A-2)}$$

In Appendix Fig. 1-(b),

$$(L_c - L_{0.25}) \cdot y_c = \int_a^c y(l)\,dl \qquad \text{(A-3)}$$

$$(L_n - L_{0.75}) \cdot 1.0 = \int_c^b y(l)\,dl \qquad \text{(A-4)}$$

Above $\int y(l)\,dl$ can be calculated applying the Trapezoidal method (Appendix Fig. 2-(a)) for Eq.(A-3),

$$\{(y_0 + y_1)/2\}\,h,\ \{(y_1 + y_2)/2\}\,h, \cdots\cdots,\ \{(y_{m-2} + y_{m-1})/2\}\,h,\ \{(y_{m-1} + y_c)/2\}\,h'$$

for Eq.(A-4),

$$\{(y_c + y_m)/2\}\,(h - h'),\ \{(y_m + y_{m+1})/2\}\,h, \cdots\cdots,\ \{(y_{n-2} + y_{n-1})/2\}\,h,\ \{(y_{n-1} + y_n)/2\}\,h$$

where $h = l_1 - l_0 = \cdots = l_m - l_{m-1} = \cdots = l_n - l_{n-1}$, $h' = L_c - l_{m-1}$ $(0 < h' < h)$.

Therefore, $\int y(l)\,dl$ for Eq.(A-3) is expressed by

$$\int_a^c y(l)\,dl = \{(1/2)y_0 + y_1 + y_2 + \cdots + y_{m-2}\}\,h + (1/2)y_{m-1}(h + h') + (1/2)y_c\,h' \qquad \text{(A-5)}$$

$\int y(l)\,dl$ in Eq.(A-4) can be represented,

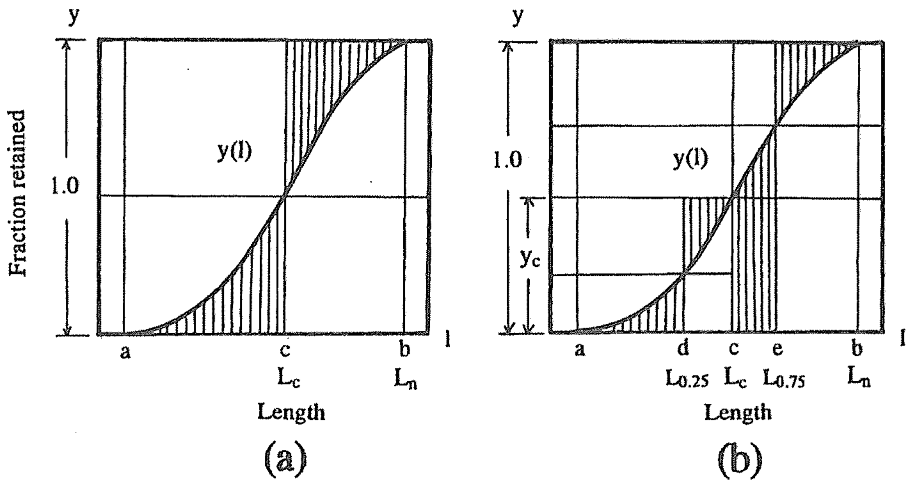
$$\int_c^b y(l)\,dl = (1/2)y_c(h - h') + (1/2)y_m(2h - h') + \{y_{m+1} + \cdots + y_{n-1} + (1/2)y_n\}\,h \qquad \text{(A-6)}$$

In Eqs.(A-3), (A-4) and (A-5), y_c (Appendix Figs. 1 and 2) is from the relation

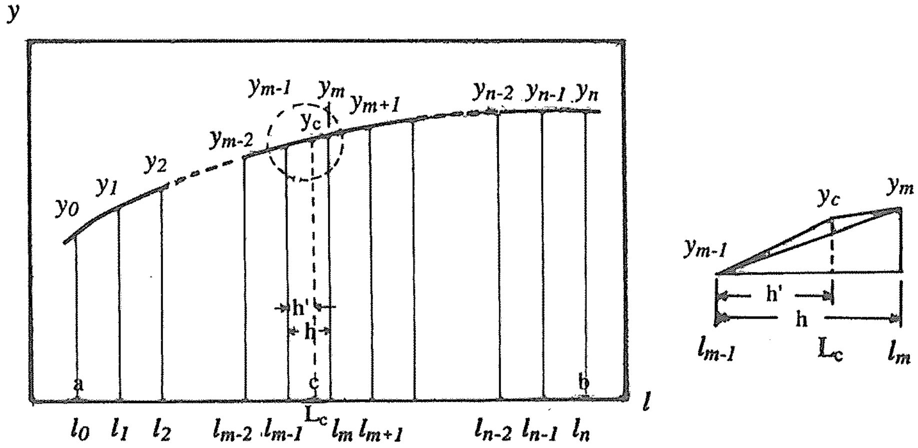
$$|(y_c - y_{m-1})/h'| = |(y_m - y_{m-1})/h| \qquad \text{(A-7)}$$

Rewriting Eq.(A-7), the y_c is presented as

$$\therefore y_c = (h'/h)y_m - |(h'/h) - 1|\, y_{m-1} \qquad \text{(A-8)}$$



Appendix Fig. 1. Nonsymmetrical selection curves. (a) Determination of mean selection length ($L_c = L_{0.50}$) for selection factor ($S.F$), (b) Determination of selection length at $L_{0.25}$ and $L_{0.75}$ for selection range ($S.R$).



Appendix Fig. 2. Trapezoidal method used for calculating areas on selection curve.

ペルー産ニベ科２魚種（*Paralonchurus peruanus*および*Sciaena deliciosa*）に対する小型トロール網コッドエンドの網目の選択性

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ペルーの小型トロール網コッドエンドの網目の選択性を調べた。実験には，コッドエンドに３インチ（7.6cm）と２インチ（5.1cm）の２種類の網目を用いた。コッドエンドの外部は全体を1 1/4インチ（3.2cm）の網でカバーした。対象魚は，ペルー中部海域のCallao沿岸産ニベ科の２種類（*Paralonchurus peruanus*：西語名「Coco」および*Sciaena deliciosa*：西語名「Lorna」）である。選択性は，選択曲線として，非対称と対称の２通りを適用して，１）50％選択体長（$L_{0.50}$，cm），２）選択域（*S.R*，cm），３）選択係数（*S.F*）の３要素から求めた。例えばCocoについて，１）非対称曲線を適用すると，３インチ網目で$L_{0.50}$=24.5cm，*S.R*=2.7cm，*S.F*=3.21，２インチで$L_{0.50}$=17.9cm，*S.R*=2.3cm，*S.F*=3.53，２）対称曲線の場合，３インチ網目で$L_{0.50}$=24.5cm，*S.R*=3.1cm，*S.F*=3.21，２インチで$L_{0.50}$=17.8cm，*S.R*=2.4cm，*S.F*=3.50という結果を得た。一方，非対称と対称の２曲線について選択性を比較したところ，１）$L_{0.50}$は非対称曲線と対称曲線でほぼ同じ値，２）非対称曲線の３インチと２インチ網目の*S.R*の値の違いは，対称曲線のそれぞれに対する値の違いより小さい，３）非対称曲線と対称曲線に対する３インチと２インチの網目の*S.F*の値は，それぞれほぼ同じとなった。本海域の主たる漁獲魚種であるCocoとLornaについて，トロール網のコッドエンドの網目の選択性が概要判明したので，網目規制の一指針が得られたことになる。