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# Mesh Selection Experiments with Beam Trawls on Shrimps (Crangon vulgaris Fabr.) off the German Coast

By

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The annual catches of shrimps caught in the German coastal fisheries from 1954 to 1961 are shown in Table 1. This table contains the total catches including also the quantities of large shrimps used for human consumption and small shrimps used dried and crushed for the feeding of animals. It can be seen that the catches decreased annually. Only in 1961 there was a little increase, but the level of the average catch for the period 1954-1958 has not been reached again.

The selection experiments have been made to find out the optimum range of cod-end mesh size in the fishery for large, edible shrimps. A higher percentage of edible shrimps in the landings will help to counterbalance the bad market for small shrimps caused by the imports of cheap fish meal.

## Method and gear

The investigations were carried out with a commercial shrimp fishing cutter having a total length of 12.9 m, a gross tonnage of 42.1 $m^3$ and a diesel engine of 75 h.p. The data were collected between 24. and 27. October within the coastal area of Büsum shown in Figure 1. As demonstrated in Figure 2, two beam trawls with different cod-ends were used simultaneously on both sides of the cutter. The design of the trawls is given in Figure 3.

The well known techniques of selection experiments are (a) the covered cod-end method, (b) the method of alternating hauls, and (c) the method of parallel hauls. During the investigations discussed a modification of the last technique was employed by using one boat instead of two. This modified method of parallel hauls gives some advantages such as saving working time and expenses, reducing the distance between the two nets to a minimum and avoiding differences in time and speed of towing as well as of the masking effect.

Generally, the fishermen in Schleswig-Holstein use a cod-end with a mesh bar of 8 mm, although they are allowed to use a cod-end of 7 mm mesh bar, measuring from the middle of the knot to the middle of the next knot. These small meshes are responsible for the high proportion of small shrimps in the landings.

During the experiments a cod-end with a mesh bar of 7.2 mm was used at the port side and cod-ends of various mesh sizes were used at the starboard side. All the cod-ends were made of nylon (see Table 2). Since the calculation of selection factors requires the knowledge of the mesh opening, this measure was also taken. The mesh opening is definedas the inside distance between two opposite knots in the same mesh, when the mesh is fully stretched. Both mesh bar and mesh opening are tabulated in Table 2. All the cod-ends investigated were covered with large-meshed heaving bags made of perlon to counteract the high strain falling on the cod-end when hauling big catches.

## Treatment of the material collected

Sixteen paired hauls were made and the duration of each varied between 30 and 120 minutes. These hauls were arranged in Table 3 according to the different fishing grounds and to the various cod-end combinations used. From every catch a representative sample was taken after removing the by-catch (fishes, crustaceans and algae). These samples were measured volumetrically with a plastic cup of 1,200 ml. Theweights of the samples were more or less the same (630-740 g), but the numbers of the individuals were scattering from 438 to 1,856 due to the size of shrimps caught. The length of 26,409 shrimps were measured in 5 mm groups from the tip of the antennae to the end of the telson. The by-catch, the large shrimps and the small shrimps were separated by means of a riddling machine and the weights were estimated in ½ kg (500 g).

## Treatment of the data

The length composition of the samples obtained from the three cod-end combinations tested (having mesh bars of 5.6 or 10.7 or 12.7 mm at the starboard and 7.2 mm mesh bar in the standard cod-end at the port side) has been compared in Figures 4-6. These figures show clearly the effect of mesh sizes on the length composition of the shrimps caught. The selectivity of the cod-ends tested, however, can be demonstrated more explicitly by comparing the weights of large shrimps with those of small chrimps caught in the cod-ends on both sides of the ship. This is done in Tables 4-6, from which it can be seen that:-

1. The 5.6 mm cod-end is catching the same quantity of large shrimps as the 7.2 mm cod-end, but more of the small shrimps (Table 4).
2. The 10.7 mm cod-end is catching somewhat more large shrimps than the 7.2 mm cod-end, but less of the small shrimps (Table 5).
3. The 12.7 mm cod-end is catching somewhat less large shrimps than the 7.2 mm cod-end, but much less of the small shrimps (Table 6).

The weights of the by-catches do not seem to be affected to a remarkable degree by the mesh size of the cod-ends.

Table 7 demonstrates the average weight percentages of large and small shrimps found for each cod-end. It can be seen that the proportion of large edible shrimps increases with the increase of mesh size, whereas the proportion of small shrimps decreases.

From these data it may be supposed that the most suitable mesh size for catching large shrimps off the German coast is about 11 mm (mesh bar). This mesh size will increase the catch of edible shrimps compared with the yield obtained by the 8 mm cod-ends used today.

Calculation of the selection factors

If the selection ranges of the two cod-ends used simultaneously do not overlap each other, it is clear that the 50% retention length of the larger-meshed cod-end B is that length of shrimp, the frequency of which in the smaller-meshed cod-end A is double that occurring in the larger-meshed cod-end. In order to determine the selection factors the samples collected from each cod-end combination were added. To transfer the true relationship between the quantities of the total catches to the samples, the length frequencies of the samples taken from the larger-meshed cod-ends have been multiplied with the quotient.

$$\frac{\text{total catch of cod-end B } (\frac{1}{2}\text{ kg})}{\text{total catch of cod-end A } (\frac{1}{2}\text{ kg})}$$

These quotients are derived from Table 8. After this all the length frequencies were treated as follows

$$x = \frac{\text{frequency B}}{\text{frequency A}} \times 100$$

in order to get the percentage ratios. These percentages were smoothed in Table 9 ($x_1$) and representated graphically in Figure 8. The selection data derived from these selection curves are shown in Table 10. There seems to be an interdependence between the selection factors calculated for the added hauls and the mean catch weights (Figure 9).

The relationship between selection factors and catch sizes can be demonstrated more clearly, when the selection factors are calculated individually for each haul. The broken lines shown in Figure 10, which are fitted by eye, have a different slope (compare the scales of the abscisses). This supports the assumption that the relation between selection factors and catch sizes is not linear. The fact that the selection factors are not only dependent on the catch size but also on the mesh size, involves a further complication. When the mesh size increases the catch size decreases and accordingly the selection factor increases. That means both factors, catch size and mesh size, are affecting the 50% retention length in an antagonistic manner.

In order to avoid the complications caused by the influence of many factors on the selection, it was tried to treat separately the two most important factors: catch size and mesh size. This has been done in Figure 11 by plotting the 50% retention length of each haul against the catch size multiplied with the selection factor. The product mentioned contains the mesh size, because the selection factor is defined as

$$sf = \frac{50\% \text{ retention length}}{\text{mesh opening}}$$

This distribution of the points + in Figure 11 can be described rather exactly by the formula

$$W \times sf = k \times L^{-n}$$

$$\text{or} \qquad \log (G \times sf) = \log K - n \times \log L$$

($W$ = catch size in $\frac{1}{2}$ kg, sf = selection factor, $L$ = 50% retention length, n and k 3 constants).

The constants k and n can be calculated from the equations

$$\log k = \frac{\sum \log (W \times sf) \times \sum (\log L)^2 - \sum \log L \times \sum [\log L \times \log (W \times sf)]}{N \times \sum (\log L)^2 - (\sum \log L)^2}$$

and

$$n = \frac{\sum \log (W \times sf) - N \times \log k}{\sum \log L}$$

(N = number of hauls = 15)

The resulting equation

$$\log (W \times sf) = 4.7572 - 1.6287 \times \log L$$

has been used to calculate the theoretical 50% retention lengths for 15 hauls. These theoretical values are expressed by x in Figure 11. There are only three experimental points deviating very much from the theoretical ones, but 12 points are nearly fitted to the theoretical curve.

The content of Figure 11 interprets that the 50% retention length is high, when the catch size is small and/or the mesh opening is large. On the other hand the 50% retention length is low, when the catch size is large and/or the mesh opening small. The 50% retention length is not affected to a high degree, when the values on the absciss are ranging in higher numbers, but on the contrary, it is affected very much, when the values on the absciss are ranging in lower numbers.

## Discussion

It may be supposed that with the use of a suitable mesh size, that is to say about 11 mm mesh bar, the shrimp fishery off the German coast will give a higher quantity of large shrimps. At the same time the amount of small shrimps will be reduced. This will help to facilitate the market condition. Moreover, the shrimp stock may be protected to a certain extent for a better production in the future.

It is known from the Büsum area that the female shrimps ripen at a mean length of 54 mm and the male shrimps at 40 mm length. If the 50% retention length for the cod-ends used could be adjusted to 40 mm, then the stock of shrimps in this area will not be affected essentially by the fisheries..

By the help of the equation describing the curve in Figure 11 it is possible to calculate the mesh opening and the mean catch size, which are correlated with the 50% retention length of 40 mm. However, in doing so, it is indispensable to calculate the mean of all the selection factors obtained ranging from 1.3 to 3.3. This mean has been found to be 2.41. According to Figure 11 the 50% retention length (that is in this case 40 mm) is correlated with an abscissa value of 141.

Expressed mathematically we have now

$$W \times sf = 141$$

and besides the formula for the selection factor

$$sf = \frac{L}{\text{mesh opening}}$$

Substituting now sf and L, the mean catch size is found to be 29.2 kg and the mesh opening is found to be 16.6 mm. The latter corresponds with a mesh bar of nearly 11 mm (see Table 2). This theoretical mesh size corresponds with the mesh size suggested according to the practical results.

The theoretical weights of the mean catches and the theoretical mesh sizes for some other 50% retention lengths are given in Table 11.

## Reference [1)]

Bohl, H., & Koura, R. . "Selektionsversuche mit Garnelenkurren vor der nord-friesischen Küste". Protok. z. Fischereitech., 8: 1-33. 1962.

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1) This paper is an abstract from the paper cited below.

Table 1

Annual yield of the German shrimp fisheries in tons

| Year | Total catch | Large shrimps | Small shrimps |
|---|---|---|---|
| Average 1954/58 | 33,012 | 5,725 | 27,737 |
| 1958 | 28,349 | 6,036 | 22,313 |
| 1959 | 25,686 | 4,414 | 21,272 |
| 1960 | 24,015 | 3,626 | 20,389 |
| 1961 | 26,817 | 4,486 | 22,331 |

Table 2

Material, mesh sizes and thickness of the knots of the cod-ends used

| Material | Mesh bar ordered (mm) | Mesh bar measured (mm) | Mesh opening (mm) | Thickness of the knots (mm) |
|---|---|---|---|---|
| Nylon Td 210x 9 | 6 | 5.6 | 8.2 | 2.3 |
| Nylon Td 210x12 | 8 | 7.2 | 11.5 | 2.9 |
| Nylon Td 210x15 | 10 | 10.7 | 16.1 | 3.4 |
| Nylon Td 210x15 | 12 | 12.7 | 19.4 | 3.4 |

Table 3

Number of hauls with different cod-end combinations on different fishing grounds

| Fishing ground | Number of hauls carried out with cod-end combination Port./Sarboard 7.2 mm/5.6 mm | Port./Starboard 7.2 mm/10.7 mm | Port./Starboard 7.2 mm/12.7 mm |
|---|---|---|---|
| Sandloch | 2 | 3 | - |
| Wesselburener Loch | - | - | 5 |
| Süder Piep | - | 3 | - |
| Norder Piep | 2 | - | - |
| Fahrwasser von Büsum | 1 | - | - |

Table 4

Weights of large shrimps, small shrimps and by-catches in ½ kg
Cod-end combination 7.2 mm/5.6 mm

| Haul No. | 7.2 mm cod-end Large shrimps | Small shrimps | By-catch | 5.6 mm cod-end Large shrimps | Small shrimps | By-catch |
|---|---|---|---|---|---|---|
| 9 | 12 | 70 | 45 | 12 | 75 | 45 |
| 10 | 15 | 70 | 33 | 15 | 75 | 33 |
| 11 | 35 | 70 | 33 | 35 | 75 | 33 |
| 12 | 35 | 80 | 12 | 35 | 100 | 12 |
| 13 | 12 | 40 | 5 | 15 | 50 | 5 |
| Total | 109 | 330 | 128 | 112 | 375 | 128 |
| Average | 22 | 66 | 26 | 22 | 75 | 26 |

Table 5

Weights of large shrimps, small shrimps and by-catches in ½ kg
Cod-end combination 7.2 mm/10.7 mm

| Haul No. | 7.2 mm cod-end Large shrimps | Small shrimps | By-catch | 10.7 mm cod-end Large shrimps | Small shrimps | By-catch |
|---|---|---|---|---|---|---|
| 1 | 60 | 225 | 14 | 60 | 180 | 16 |
| 2 | 55 | 225 | 12 | 55 | 180 | 12 |
| 3 | 20 | 60 | 17 | 20 | 40 | 17 |
| 14 | 20 | 45 | 16 | 20 | 30 | 16 |
| 15 | 20 | 60 | 53 | 20 | 40 | 53 |
| 16 | 70 | 300 | 6 | 90 | 300 | 6 |
| Total | 245 | 915 | 118 | 265 | 770 | 120 |
| Average | 41 | 153 | 20 | 44 | 128 | 20 |

Table 6

Weights of large shrimps, small shrimps and by-catches in $\frac{1}{2}$ kg
Cod-end combination 7.2 mm/12.7 mm

| Haul No. | 7.2 mm cod-end Large shrimps | Small shrimps | By-catch | 12.7 mm cod-end Large shrimps | Small shrimps | By-catch |
|---|---|---|---|---|---|---|
| 4 | 20 | 50 | 50 | 15 | 10 | 50 |
| 5 | 15 | 45 | 60 | 10 | 15 | 70 |
| 6 | 20 | 30 | 50 | 20 | 15 | 50 |
| 7 | 7 | 20 | 8 | 7 | 10 | 12 |
| 8 | 10 | 120 | 3 | 10 | 40 | 3 |
| Total | 72 | 265 | 171 | 62 | 90 | 185 |
| Average | 14 | 53 | 34 | 12 | 18 | 37 |

Table 7

Weight percentages of large and small shrimps in the average catch of each cod-end (without by-catch)

| Mesh bar (mm) | Number of hauls | Large shrimps (%) | Small shrimps (%) |
|---|---|---|---|
| 5.6 | 5 | 23 | 77 |
| 7.2 | 16 | 22 | 78 |
| 10.7 | 6 | 26 | 74 |
| 12.7 | 5 | 40 | 60 |

Table 8

Derivation
~~Deviation~~ of the conversion factors from the catch size

| Cod-end | Mesh bar (mm) | Weight of shrimps per catch ($\frac{1}{2}$ kg) | Total catch ($\frac{1}{2}$ kg) | Total catch B / Total catch A |
|---|---|---|---|---|
| B | 7.2 | 82+85+105+115+52 | 439 | 0.90 |
| A | 5.6 | 87+90+110+135+65 | 487 | |
| B | 10.7 | 240+235+60+50+60+390 | 1,035 | 0.89 |
| A | 7.2 | 285+280+80+65+80+370 | 1,160 | |
| B | 12.7 | 25+25+35+17+50 | 152 | 0.45 |
| A | 7.2 | 70+60+50+27+130 | 337 | |

Table 10

Selection data of cod-end used

| | 7.2 mm cod-end | 10.7 mm cod-end | 12.7 mm cod-end |
|---|---|---|---|
| 50% retention length (mm) | 26.5 | 32.5 | 53.5 |
| Mesh opening (mm) | 11.5 | 16.1 | 19.4 |
| Selection factor | 2.3 | 2.0 | 2.8 |

Table 11

Theoretical relationship between 50% retention length, catch size and mesh sizes for a selection factor of 2.41

| 50% retention length (mm) | Catch size ($\frac{1}{2}$ kg) | Mesh opening (mm) | Mesh bar (mm) |
|---|---|---|---|
| 30 | 93.2 | 12.4 | 7.8 |
| 40 | 58.4 | 16.6 | 11.0 |
| 50 | 40.6 | 20.7 | 13.6 |

Table 9. Relative length composition of the total catches and determination of the selection curves (Explanation in the text).

| i<br>Length (mm) | Cod-end A 5.6 mm | Cod-end B 7.2mm | x(%) 7.2 mm / 5.6 mm | $x_i$ | Cod-end A 7.2 mm | Cod-end B 10.7 mm | x(%) 10.7 mm / 7.2 mm | $x_i$ | Cod-end A 7.2 mm | Cod-end B 12.7 mm | x(%) 12.7 mm / 7.2 mm | $x_i$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.5 | 20 | 7 | 35 | - | 13 | 3 | 23 | - | 8 | | | |
| 17.5 | 89 | 14 | 16 | 28 | 35 | 11 | 31 | 29 | 21 | 1 | 5 | - |
| 22.5 | 190 | 64 | 34 | 35 | 204 | 66 | 33 | 33 | 197 | 12 | 6 | 7 |
| 27.5 | 394 | 213 | 54 | 54 | 565 | 199 | 35 | 40 | 533 | 46 | 9 | 9 |
| 32.5 | 605 | 452 | 75 | 70 | 772 | 410 | 53 | 50 | 792 | 104 | 13 | 15 |
| 37.5 | 703 | 586 | 81 | 79 | 967 | 600 | 62 | 66 | 550 | 119 | 22 | 20 |
| 42.5 | 933 | 747 | 80 | 84 | 1067 | 891 | 83 | 79 | 725 | 177 | 24 | 29 |
| 47.5 | 699 | 639 | 91 | 87 | 889 | 820 | 92 | 96 | 564 | 223 | 40 | 37 |
| 52.5 | 452 | 402 | 89 | 91 | 510 | 575 | 113 | 104 | 446 | 205 | 46 | 51 |
| 57.5 | 157 | 147 | 94 | 91 | 204 | 221 | 108 | 107 | 172 | 113 | 66 | 56 |
| 62.5 | 163 | 149 | 91 | 102 | 190 | 191 | 101 | 104 | 181 | 101 | 56 | 64 |
| 67.5 | 116 | 139 | 120 | 111 | 163 | 167 | 102 | 99 | 137 | 97 | 71 | 61 |
| 72.5 | 47 | 58 | 123 | 118 | 77 | 73 | 95 | 90 | 94 | 53 | 56 | 65 |
| 77.5 | 18 | 20 | 111 | - | 35 | 26 | 74 | - | 46 | 31 | 67 | 66 |
| 82.5 | 2 | 1 | | | 2 | | | | 4 | 3 | 75 | - |
| 87.5 | 1 | | | | | | | | | 2 | | |

Note: the frequencies given for the cod-ends B are corrected by the conversion factors tabulated in Table 8.

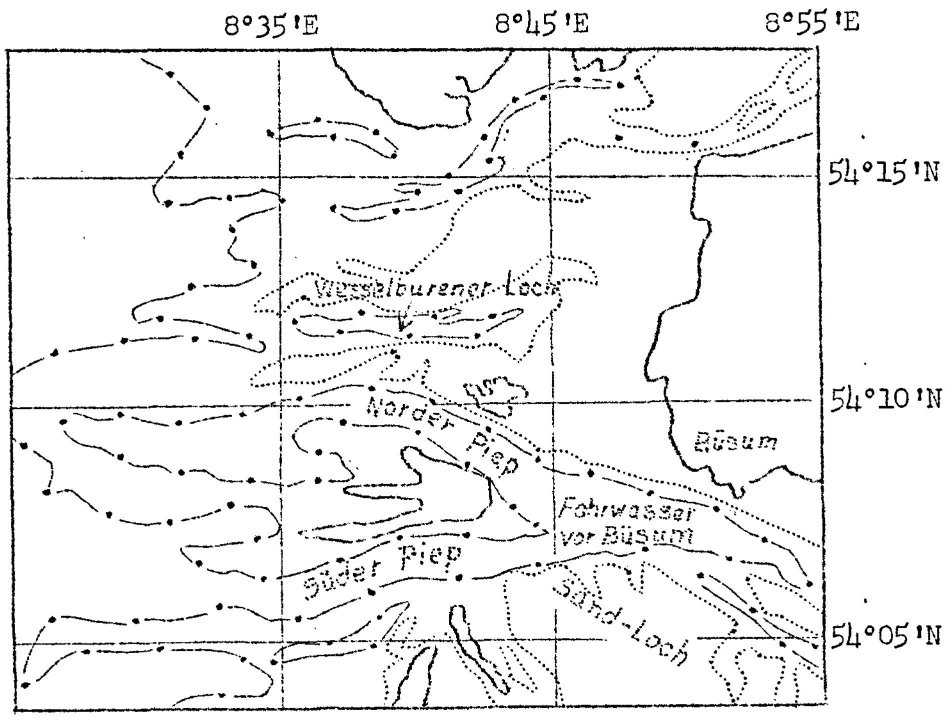


Figure 1. Area of fishing grounds.

—·—·—·— 5 m depth line

.................. 1 m depth line

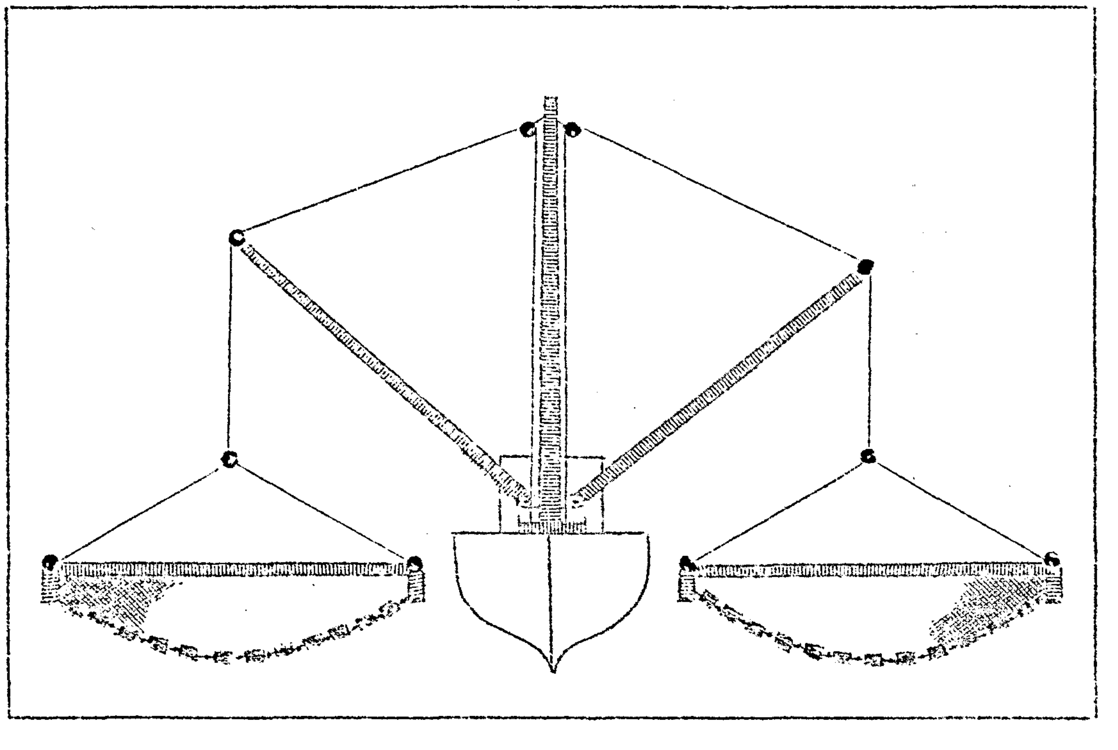

Figure 2. Scheme of a shrimp cutter with two beam trawls.

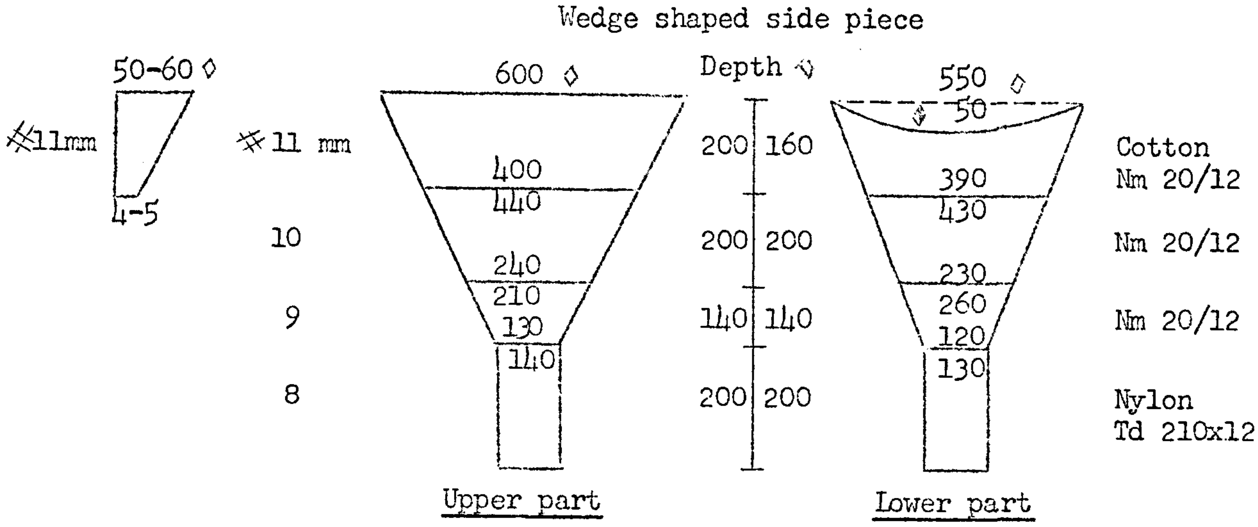


Figure 3. Construction of the net.

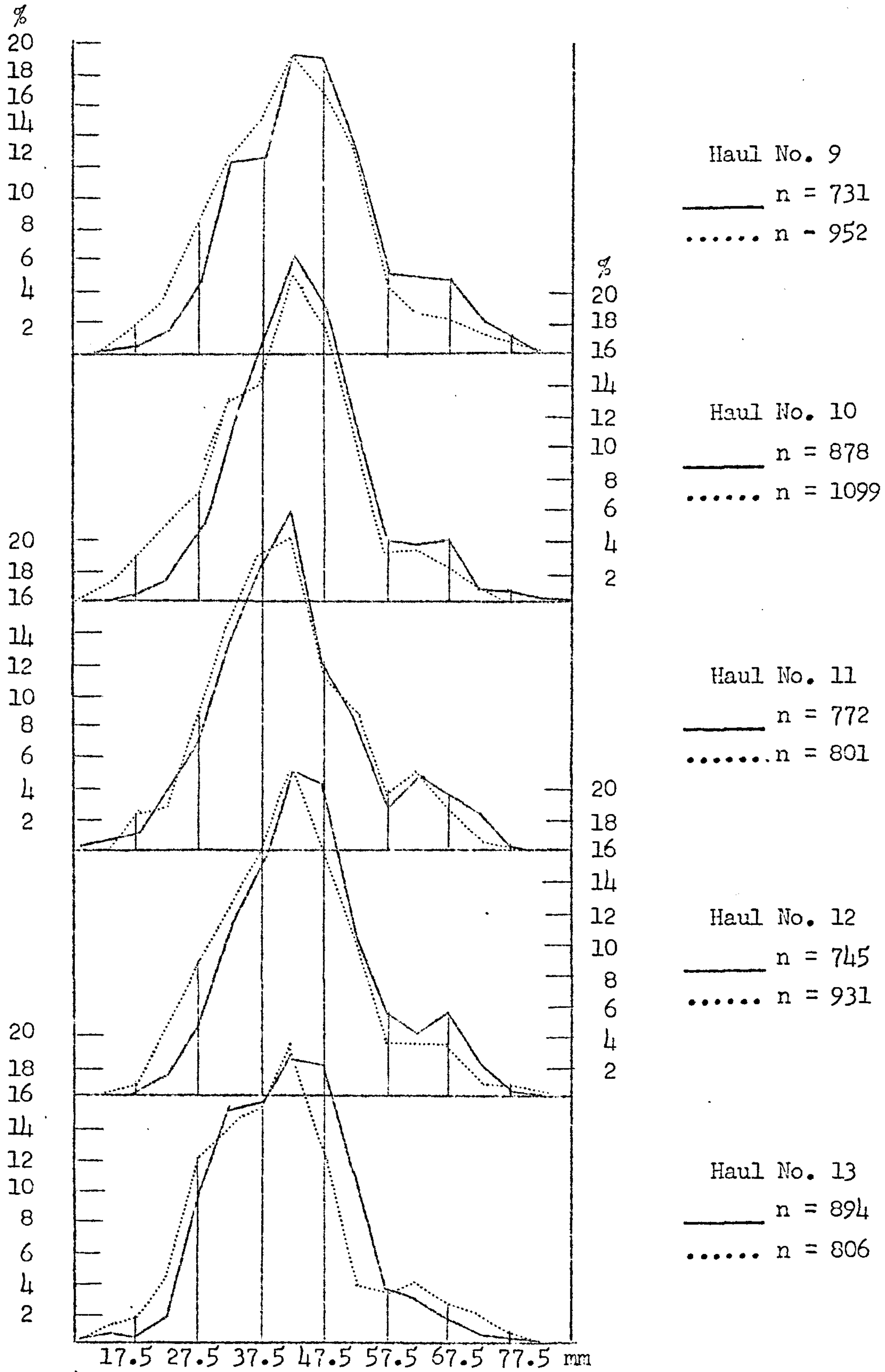


Figure 4. Length frequency polygons of the samples.
—— 7.2 mm cod-end .... 5.6 mm cod-end

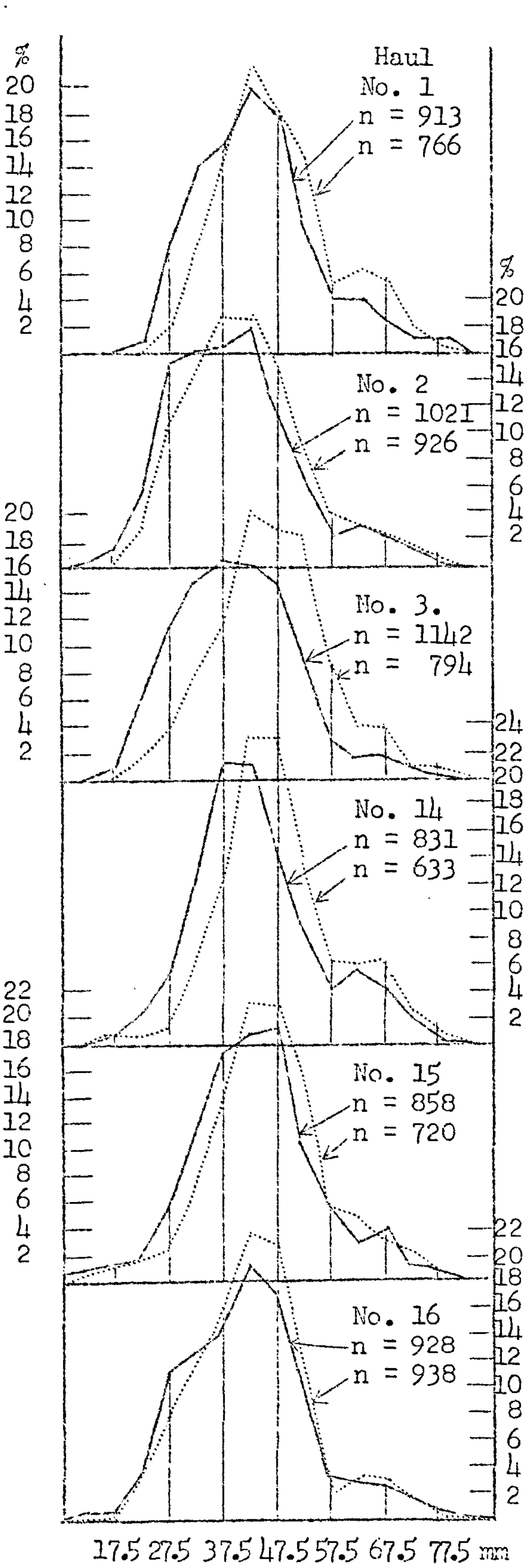


Figure 5. Length frequency polygons of the samples.

_____ 7.2 mm cod-end
......10.7 mm cod-end

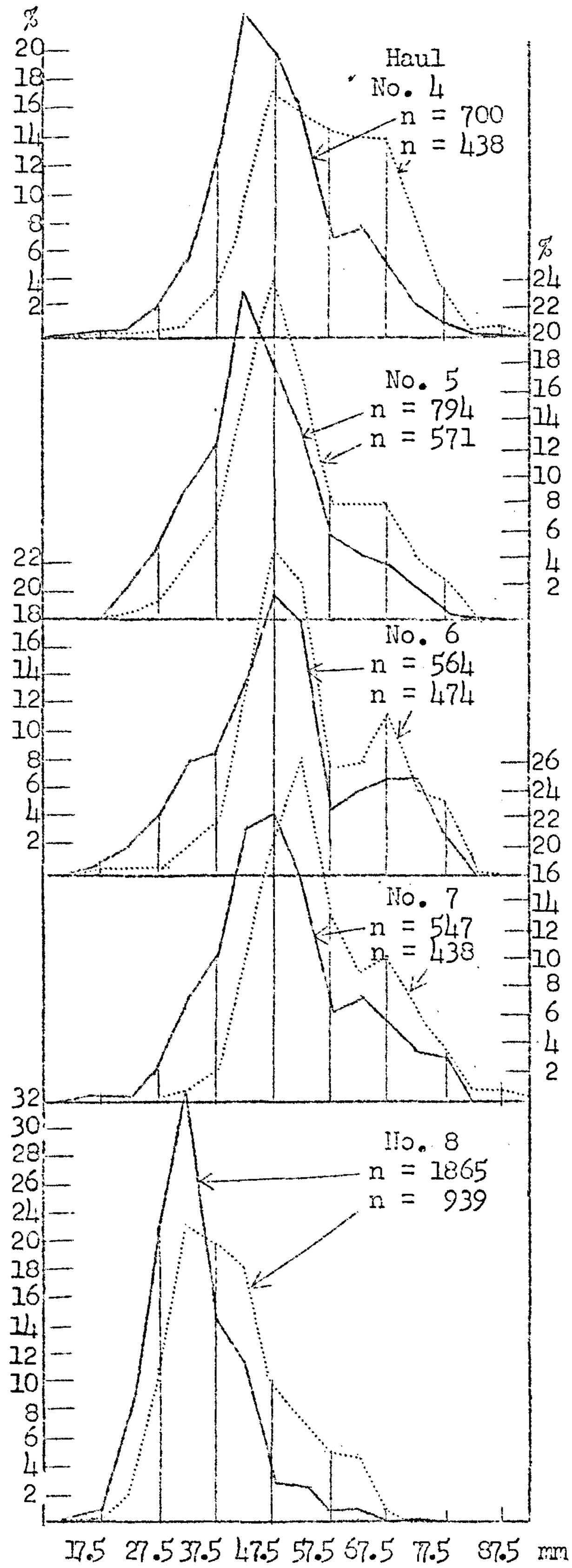


Figure 6. Length frequency polygons of the samples.

_____ 7.2 mm cod-end
......12.7 mm cod-end

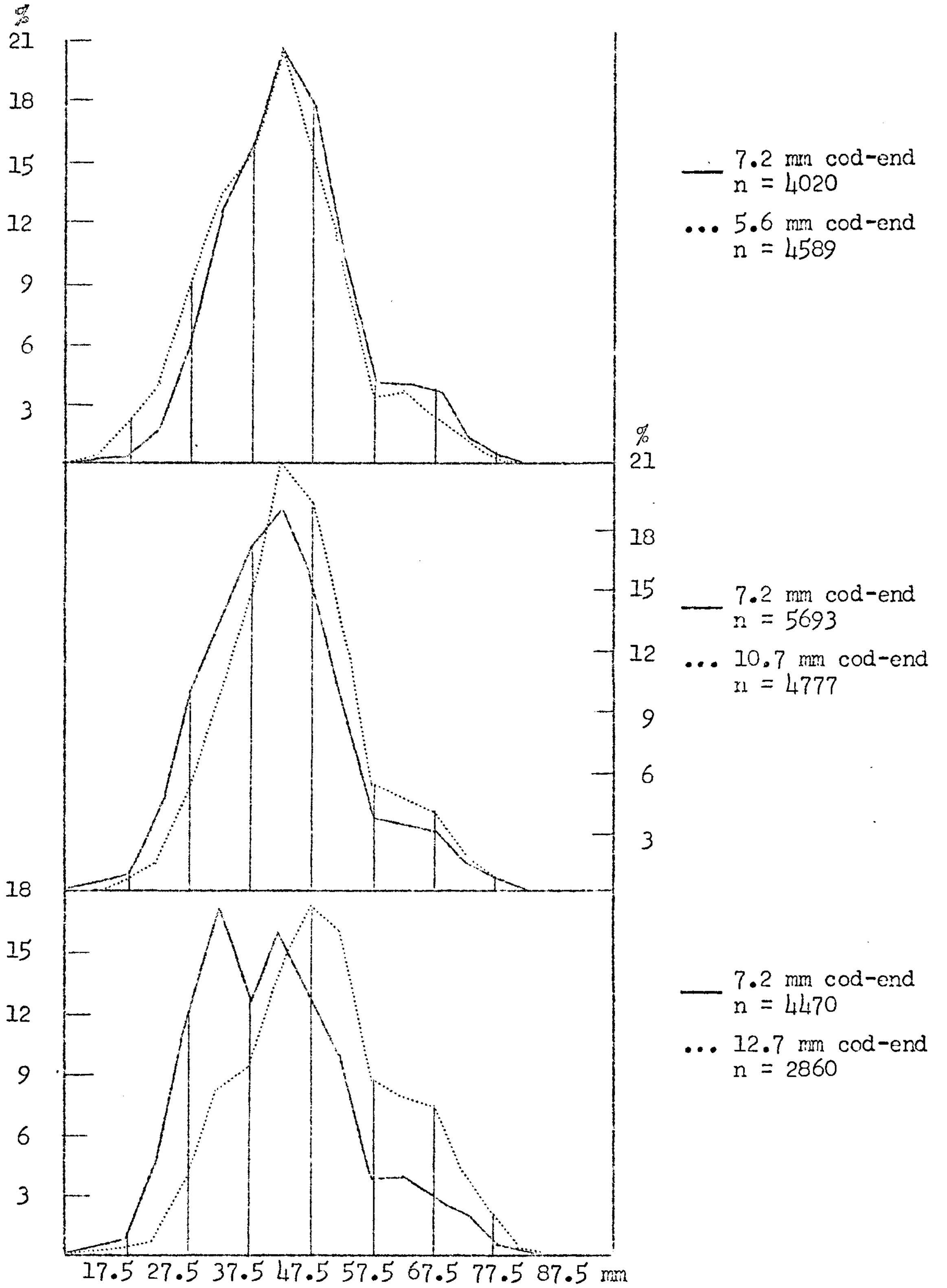


Figure 7. Length frequency polygons for the added samples of the cod-end combinations.

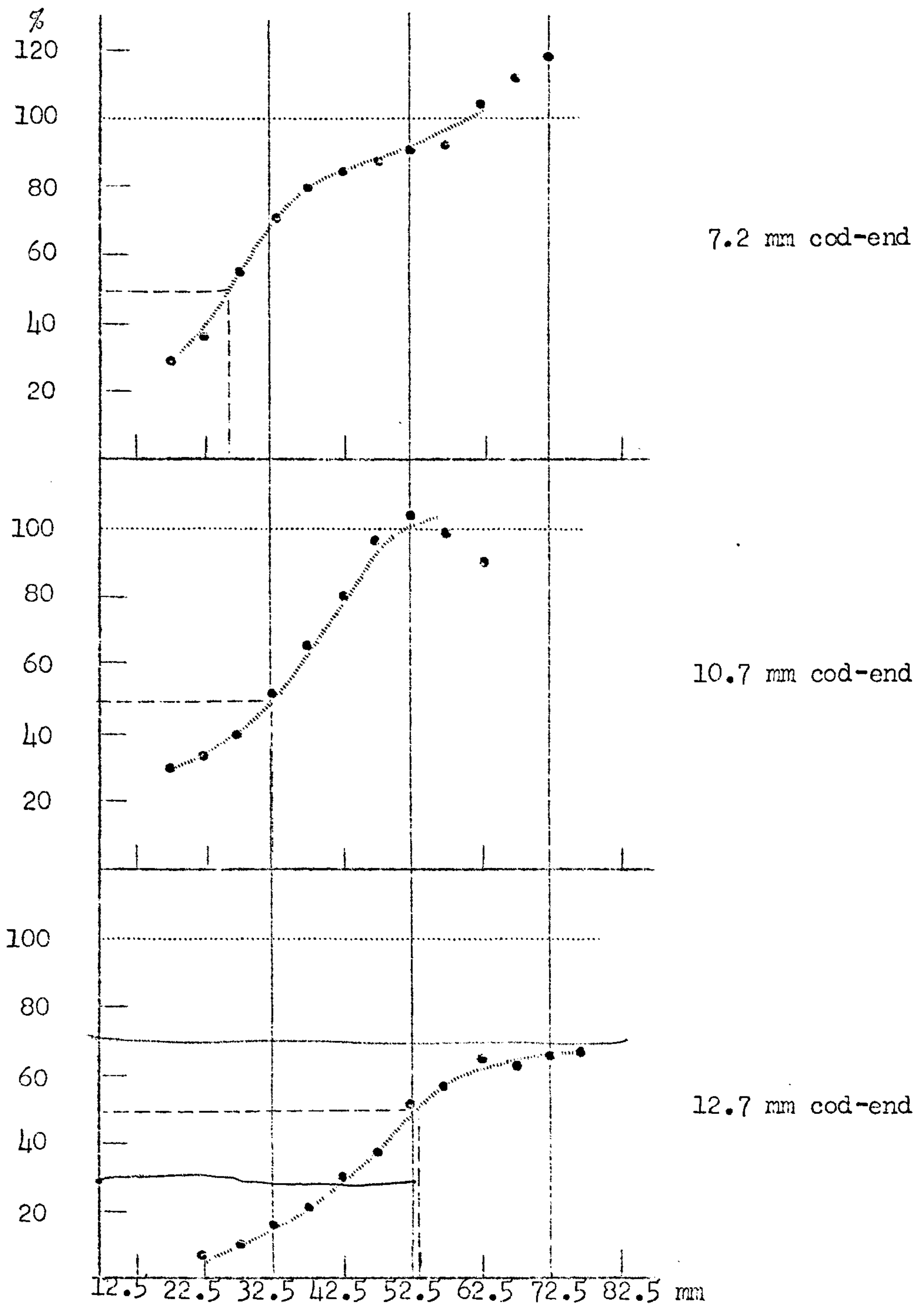


Figure 8. Selection curves.

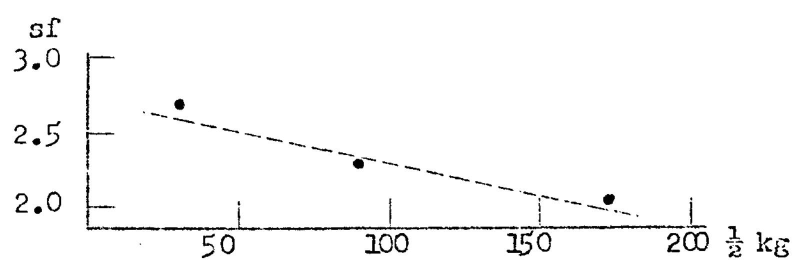


Figure 9. Relation between selection factor and mean catch size for added hauls.

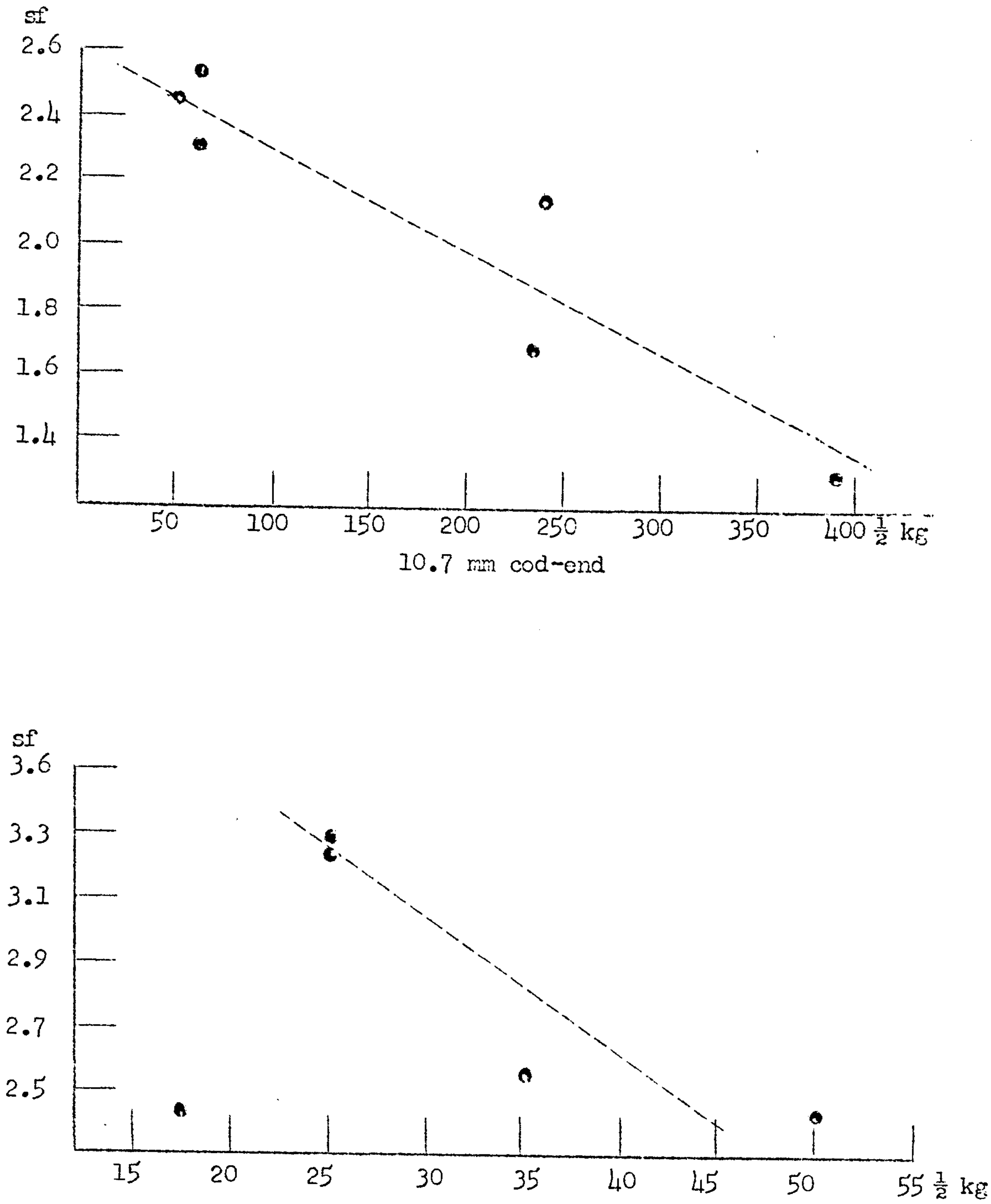


Figure 10. Relation between selection factor and catch size.

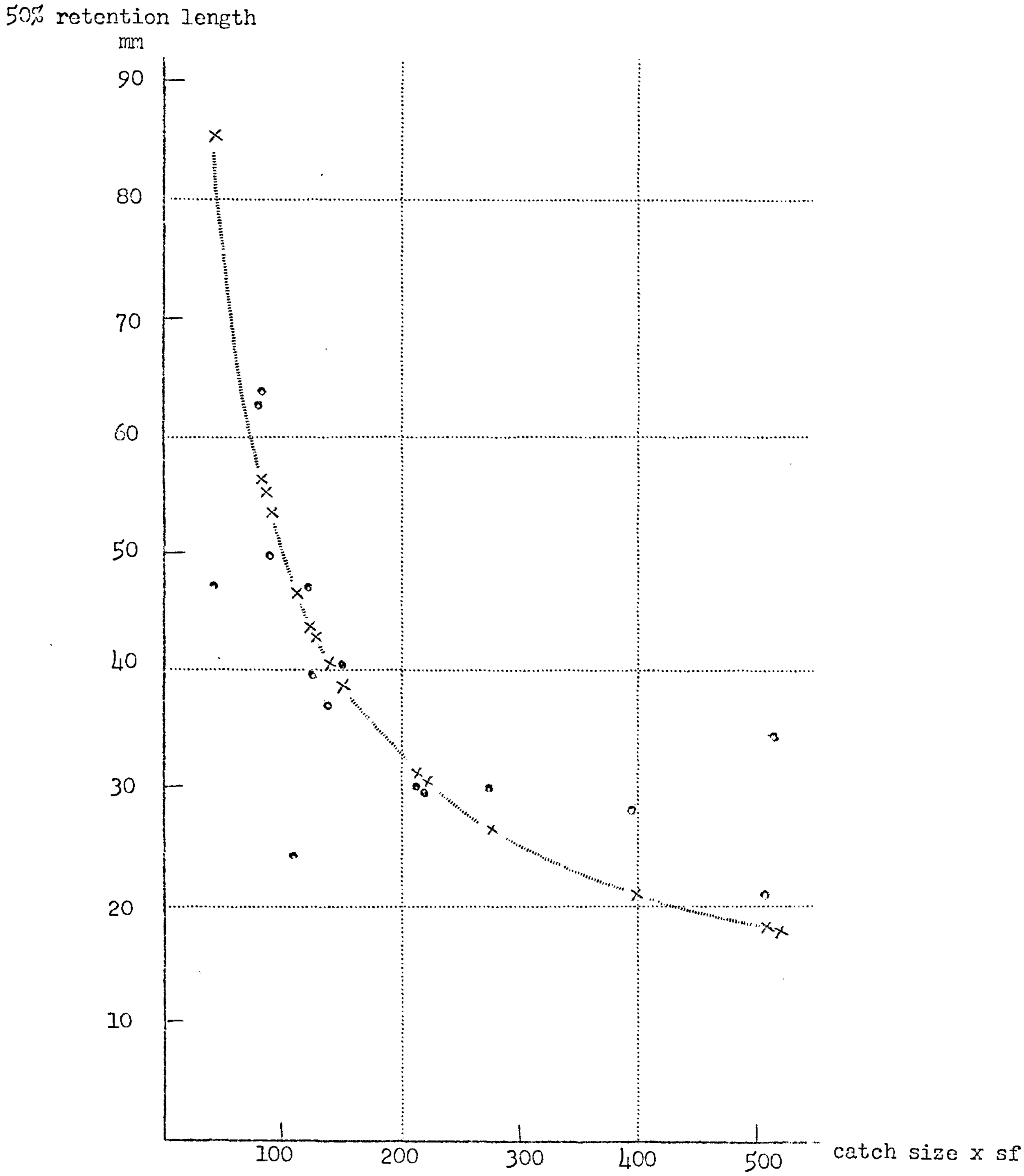


Figure 11. Relation between the 50% retention length
and the value of catch size x selection factor.