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PRELIMINARY APPRAISAL OF ANTARCTIC FISH SELECTION BY THE 32/36 BOTTOM TRAWL COMBINED WITH VARIOUS CODENDS

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Abstract

Selectivity properties of single and doubler-layer twine codends (mesh size 120 mm) and single-layer tape codends with a mesh size of 60 and 100 mm were determined. It was found that the selectivity properties of twine codends are unsatisfactory in the case of Antarctic icefish, bumphead notothenia, and Scotia Sea icefish. This was primarily caused by the heavy net material used for their construction, incorrectly chosen mesh size, and certain morphological features of some Antarctic fish, which make it difficult for them to escape from the codend. Selectivity properties of both tape codends were much better. It was found that an optimum mesh size of this codend for selection of Antarctic icefish and bumphead notothenia ranges from 60 to 100 mm. For other Antarctic fish, especially Scotia Sea icefish and South Georgia icefish the determination of a proper mesh size of trawls used in fishing for them requires further research. It should first of all cover twine codends with a mesh size of 80 mm, currently used on factory trawlers, as well as codends with a structure resembling tape codends.

Résumé

Ont été déterminées les propriétés de sélectivité des culs de chalut simples ou doublés à cordes (taille du maillage 120 mm) et des culs de chalut simples à rubans plats (taille du maillage 60 et 100 mm). Il s'est avéré que les propriétés de sélectivité des culs de chalut à cordes n'étaient pas adéquates dans le cas des poissons des glaces de l'Antarctique, des Notothenia gibberifrons et des poissons des glaces de la Mer de Scotia; les raisons principales étant : l'utilisation d'un matériau lourd dans leur construction, le choix inapproprié de la taille du maillage, et certains aspects morphologiques de certains poissons antarctiques qui les empêchent de s'échapper du cul de chalut. Les propriétés de sélectivité des deux culs de chalut à rubans plats étaient bien meilleures. L'on a constaté que la taille de maillage optimale de ce cul de chalut pour la sélection des poissons des glaces de l'Antarctique et des Notothenia gibberifrons allait de 60 à 100 mm. Pour ce qui est des autres poissons antarctiques, en particulier les poissons des glaces de la Mer de Scotia et ceux de la Géorgie du Sud, des recherches complémentaires seront nécessaires pour

déterminer la taille de maillage appropriée des chaluts servant à les pêcher. Ces recherches auront tout d'abord pour objet les culs de chalut à cordes dont la taille de maillage est de 80 mm et qui sont actuellement utilisés sur les chalutiers-usines, ainsi que les culs de chalut dont la structure ressemble aux culs de chalut à rubans plats.

Resumen

Se determinaron las propiedades de selectividad de las mallas de corona de soga trenzada de simple y doble capa (luz de malla de 120 mm) y las mallas de corona de cinta de capa simple con una luz de malla de 60 y 100 mm. Se encontró que las propiedades de selectividad de las mallas de corona de soga trenzada son insatisfactorias en el caso del pez de hielo de la Antártida, Notothenia gibberifrons (bumphead notothenia) y del pez de hielo del Mar de Scotia. Esto fue causado principalmente por el pesado material de red usado para su construcción, la luz de malla incorrectamente escogida y ciertas características morfológicas de algunos peces antárticos, que dificultan su escape de la corona. Las propiedades de selectividad de ambas mallas de corona de cinta resultaron ser mucho mejores. Se encontró que el rango óptimo de la luz de malla de esta corona para la selección del pez de hielo de la Antártida y de Notothenia gibberifrons (bumphead notothenia) es de 60 a 100 mm. Para otro peces de hielo de la Antártida, especialmente el pez de hielo del Mar de Scotia y el pez de hielo de Georgia del Sur, la determinación de una luz de malla adecuada de los arrastres usados para la pesca de los mismos requiere mayor investigación. En primer lugar debería cubrir las mallas de corona de soga trenzada con una luz de malla de 80 mm, utilizada actualmente en los arrastreros factoría, así como las mallas de corona de estructura semejante a las mallas de corona de cinta.

Резюме

Были определены селективные способности одно- и двуслойных веревочных кутков (размер ячеи - 120 мм) и однослойных ленточных кутков с размером ячеи в 60 и 100 мм. Селективные способности веревочных кутков были найдены неподходящими в случае ледяной рыбы, зеленой нототении и ледяной рыбы моря Скотия. В первую очередь это было вызвано использованием тяжелого сетного полотна при их конструировании, неправильным выбором размеров ячей и определенными морфологическими характеристиками некоторых антарктических рыб, что создает затруднения при попытке рыбы высвободиться из кутка. Селективные

способности обоих ленточных кутков были гораздо лучше. Было найдено, что оптимальный размер ячей такого кутка при селекции ледяной рыбы и зеленой нототении варьируется от 60 до 100 мм. Для других видов антарктической рыбы, особенно для ледяной рыбы моря Скотия и ледяной рыбы Южной Георгии, определение подходящих размеров ячеи в тралах, используемых при промысле этих видов, требует дальнейших исследований. Они должны в первую очередь охватить веревочные кутки с размером ячеи в 80 мм, используемые в настоящее время на плавучих рыбзаводах, а также кутки, структура которых напоминает ленточные.

PRELIMINARY APPRAISAL OF ANTARCTIC FISH SELECTIVITY BY THE 32/36 BOTTOM TRAWL WITH VARIOUS CODENDS

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The necessity of introducing regulatory measures for the Antarctic fishery is no longer a disputable matter; the problem is to select the best measures from the biological, technical and legal point of view. One of the effective methods of regulating catch may be the determination of minimum allowable mesh size in the codend for each commercial species of fish. Since no extensive investigations of this kind have been carried out in the Antarctic so far, it is valuable to publish the results of Polish experimental research in the 1978/1979 season despite the fact that types of net materials, their mesh sizes, and constructions (tape nettings) used in the codends were not typical for fishing operations in the Antarctic. The results presented below may constitute a starting point for further work in this field but are not in themselves a basis for regulating mesh size in the codend of trawls used for fishing in the Antarctic.

1. GENERAL INFORMATION ABOUT THE CRUISE AND TRAWL SELECTIVITY INVESTIGATIONS

The investigations of trawl selectivity were just a part of complex oceanographical and ichthyological investigations carried out between December 1978 and March 1979 on the research vessel Professor Siedlecki. The selectivity investigations were conducted in the following areas :

1. South Georgia, i.e. fishing grounds on the shelf of South Georgia and Shag Rocks,

2. South Orkney Islands,

3. Antarctic Peninsula, including the following fishing grounds : Elephant Island, Joinville Island, South Shetland Islands, Palmer Archipelago and Biscoe Archipelago.

A total of 139 tows were made during the whole cruise, including 118 bottom ones. The selectivity of various codends was tested in bottom tows (in 14 mid-water tows only krill was taken). Out of 112 tows, in which a total of 94 877 fish were measured (65 954 in the codend itself and 28 923 in the fine meshed liner), only those were selected for the determination of trawl selective properties which fulfilled the basic assumptions, described in more detail in the section on methods. All selectivity investigations were described in a report from the IVth Polish Antarctic expedition in the 1978/1979 season. On the basis of those results, it is possible to present here the results of investigations of those fish species for which the most abundant and representative data were collected. Fishing areas and the number of tows constituting the basis for calculations for each species and type of codend are given when discussing individual selectivity ogives.

2. STRUCTURE OF CODENDS

Two types of codends (single- and double-layer) were used for selectivity studies. A single-layer codend was made of one type of net material forming codend walls while a double-layer construction consisted of two types of net materials : the net with smaller meshes ensuring fish selectivity and an outer chafer with larger meshes, reducing and preventing damage of the codend. Table 1 presents details of the trawl construction and the characteristics of materials used for various codends tested. Single- and double-layer twine codends were very similar in construction to standard ones used in other fishing grounds, with a nominal mesh size of 120 mm (dry). Tape codends were made of different materials and had different material characteristics. Size of meshes in these codends was converted for comparison to a value known in literature as "mesh size". This value was much lower for both tape codends than for standard twine codends. It may be generally said that all investigated codends were different from each other in their material, technology, and finishing details. This fact should be borne in mind when comparing the results; the conclusions reached should not be generalized.

All investigated codends were 4-wall constructions, widening in the front to form a square inlet with sides of 4.5 m length measured with meshes stretched. All investigated codends could easily be substituted one for another and attached to the same trawl. Schematic construction of the investigated codends is presented in Figure 1 for a tape codend with 60 mm mesh size.

It was assumed during experiments that selectivity investigations should be conducted under the conditions resembling as closely as possible those in which the gear would be normally used. Therefore, a 32/36 bottom trawl, mastered on other fishing grounds, was used. A schematic construction of this trawl is presented in Figure 2. Figure 3 shows a plan of rigging for a 32/26 trawl.

For selectivity investigations, a method with a fine-meshed liner was used. However, since the bottom on the fishing grounds was stony, a semi-liner construction was used in practice. Thus, a loose fine-meshed liner was placed on the upper part of the codend, reaching down to the middle of the codend side walls.

The codend bottom was deprived of its selective properties up to the middle of side walls by placing inside it, the same fine-meshed inset. In this way, fish in the codend could escape only through the meshes of the upper trawl part to the cover. The fine-meshed liner was made from a steelon twine with a thickness of 2 mm and having a mesh size of 20 mm. A schematic drawing of a 4-wall codend with fine-meshed liner is presented in Figure 4.

In order to make it easier to empty the trawl on board, the codend and cover were equipped like a standard commercial codend with 4 splitting straps made of a rope with a thickness of 30 mm (version I), Figure 5. Since there was a danger that those heavy straps lying on the fine-meshed liner might change selectivity results, a second version without them was worked out during investigations : the codend used had open splitting straps. Only after hauling the codend on board, both ends of straps were connected with a shackle and the codend and liner were emptied. A schematic drawing of the modified codend gear (version II) is presented in Figure 6.

3. MATERIAL AND METHODS

In order to determine selective properties of the investigated codends, the above-mentioned method with a fine-meshed liner was used.

Mesh sizes were measured wet, after a certain number of hours of towing time, with an ICES slide caliper (load of 4 daN) and calculated as a mean from 30 measurements.

For investigations, only those tows were selected which fulfilled the following basic requirements :

- estimated total yield of the tow could not be smaller than 500 kilograms of fish,
- the investigated species constituted at least 20% of the total catch weight.

The number of tows studied and number of fish measured are presented in Tables 2 - 5, separately for various codends.

On the basis of measurements of the length of all fish, separately for the codend and fine-meshed liner, standard calculations were made to obtain selectivity parameters and ogives for a tested codend with respect to a given fish species. Basic selectivity factors, i.e. mean fish length for three main selectivity levels : 25, 50 and 75%, were determined graphically. In addition, the following basic selectivity parameters were calculated :

- selectivity interval consisting of the difference in cm between the mean length of fish for selectivity levels 75 and 25%;

- selectivity coefficient (F_s) obtained from the following formula :

$$F_s = \frac{L_{50\%}}{A}$$

where :

$L_{50\%}$ = fish length at a 50% selectivity level,
A = mean mesh size in the codend determined for a given stage of investigations (wet) ;

- selection quality coefficient (W_s) obtained from the ratio :

$$W_s = \frac{L_{50\%}}{L_{100\%}}$$

where :

$L_{50\%}$ = fish length at a 50% selectivity level,
$L_{100\%}$ = smallest fish length retained in full by the codend

If it was impossible to build a typical selectivity curve on the basis of the data collected (or even a curve resembling a typical one), the points obtained were connected by straight lines without attempting to interpolate the results.

4. RESULTS AND DISCUSSION

4.1 Selective Properties of a Double-Layer Codend

The object of investigations was a typical codend used by the Polish fishery in NAFO and NEAFC areas, with a nominal mesh size in the codend of 120 mm. This codend was equipped with a chafer with a nominal mesh size of 240 mm.

The tests were run on the fishing grounds of South Georgia, Shag Rocks and South Orkney Island on the species predominating in the catch : mackerel icefish (Champsocephalus gunnari), bumphead notothenia (Notothenia gibberifrons), and Scotia Sea icefish (Chaenocephalus aceratus).

Mackerel icefish

The ogives (Figure 7) did not resemble typical selectivity curves. A characteristic feature of mackerel icefish selection by a double-layer codend was a similar ratio of fish allowed to pass to those retained for almost all length classes. This was especially visible in catches made off South Orkney Island, where for many length classes this ratio was almost identical - slightly over 50%. On South Georgia fishing grounds, the same was true for fish of up to 35 cm in length. There could have been several reasons for this fact. It seems, however, that one of the most important was the badly chosen mesh size, which had lost selectivity ability for this species, and the double-layer structure of the codend only deepened this effect.

Bumphead notothenia

Selectivity ogives were drawn separately for South Georgia fishing grounds and South Orkney grounds (Figure 8). Both ogives were almost identical. Their initial sections fluctuated at the same level (50-70%) and starting from a certain length of fish - 35 cm - began to ascend up to a length of 46 cm; above this level a 100% of fish was retained by the codend. However, it was impossible to convincingly explain why small fish with lengths of 16-33 cm were retained at the same, equally high level in the double-layer codend.

Scotia Sea icefish

On the basis of the data presented in Table 2, only one selectivity ogive was drawn; it referred to South Georgia grounds, as the material collected off South Orkney Island was too scarce to fit the ogive (Figure 9).

The selectivity ogive for Scotia Sea icefish is similar to the ogives discussed before, its initial part reflecting the degree of retention of small fish with a length of 20 and 21 cm at a 40–50% level and fish with a length of up to 35 cm at a 80–90% level clearly ends at this length. With respect to longer fish, the codend material exhibits increasing selectivity - the curve ascends quite regularly reaching a 100% retention for icefish with a length of 44 cm. Since this curve closely resembled the previous ones, it may be said that the fish selectivity process has the same nature.

4.2 Selective Properties of Single-Layer Codends

Single-layer codends, which are not equipped with a protective chafer, are today among constructions used most frequently by commercial fisheries of various countries. That is why they were the main object of investigations on Antarctic fishing grounds.

4.2.1 Twine Codend

The twine codend made from double polyamide twines with a nominal thickness of 7 mm had a nominal mesh size of 120 mm (dry), i.e. the same as the codend in a double-layer construction.

This codend was tested on the fishing grounds off the Antarctic Peninsula (Joinville, South Shetland Island, Elephant Island) and off South Georgia and Shag Rocks. Data for the following species were collected there : mackerel icefish, bumphead notothenia, Scotia Sea icefish, ocellated icefish (Chionodraco rastrospinosus) and Patagonian toothfish (Dissostichus eleginoides).

Mackerel icefish

Separate selectivity ogives were drawn for mackerel icefish caught with the help of a single-layer twine codend on fishing grounds of South Georgia and South Shetland Islands (Figure 10). Although the curves were characterized by an upward tendency, they differed distinctly from typical selectivity curves. They were similar to the ogives for a double-layer codend with a similar mesh size, analyzed above. For similar reasons as in the case of a double-layer construction, the codend material did not have the required selective properties with respect to mackerel icefish. Only fish with a length of 51 cm were wholly retained by the codend. In this case it was also impossible to find convincing arguments to explain the reasons for the considerable retention in the codend of relatively small fish, although their shape is such that they should quite easily escape through the meshes.

Bumphead notothenia

Two selectivity ogives were drawn, separately for each fishing ground, South Georgia and South Shetland Islands (Figure 11). Both ogives are similar, consisting of two sections : the initial one characterizes the selectivity for fish with a length of up to 32 cm, the second- the selectivity for longer fish. The analysis of these ogives leads one to conclude that the codend in question retains smaller fish at a relatively high level (35-60%) and only for fish with a length exceeding 32 cm, it assumes selective properties. Starting with a length of 45 cm, all notothenia are retained by this codend.

Scotia Sea icefish

Selectivity ogives (Figure 12) for South Georgia and South Shetland Islands were fairly similar despite quite large quantitative differences. Each of the curves consisted of two segments (sections) : the first, depicting retention properties of fish up to 34 cm in length at a

relatively high level of up to 80-90%, and a second one, resembling a typical selectivity ogive. Unfortunately, this part of the curve constitutes only its final, short segment. Scotia Sea icefish with a length exceeding 43 cm were fully retained by the codend. It was difficult to explain why the net material with relatively large meshes retained fish with lengths of 16-19 cm at a level of 50-60%, and fish with lengths of 23-27 cm at a level as high as 80-90%. It is possible that the body features of Scotia Sea icefish (large head and spines on opercular bones) are responsible for small fish retention by the codend. It should be emphasized, however, that there were very few fish with lengths of 21-26 cm in the stock under investigation, which could have resulted in a misleading arrangement of selectivity data collected.

Ocellated icefish

Ocellated icefish occurred in greater quantities only on the fishing grounds of the South Shetland Islands and Elephant Island. A characteristic feature of these tows was their high yield. The length composition of ocellated icefish caught did not favour selectivity studies since fish with a length below 29 cm were very rare.

The shape of the selectivity ogive in Figure 13 resembles a typical selectivity ogive with a large descent, resulting from a narrow selection interval, equalling barely 1.6 cm. Fish with a length of 27 cm reached a 50% selection level. Under these conditions, selectivity coefficient F_s equalled 2.21, selection quality $W_s = 0.61$. The length of fish fully retained by the codend was 44 cm. Analyzing the values obtained, it was obvious that the values of selectivity parameters were very low, which could not have been anticipated. This could have been caused by the insufficient quantity of materials collected, especially as regards smaller fish. Another reason might have been the fact that materials collected came from relatively abundant tows, in which investigated fish, packed together with many other fish in the codend, could not escape as easily as in the case of a smaller catch. Another reason for the low selectivity could have been the body shape of ocellated icefish or badly chosen mesh

size. Whatever the reasons for the deformation of the selectivity curve, it must be said that the calculated data point out to the low level of selective properties of the net material examined.

Patagonian toothfish

Patagonian toothfish was caught in greater quantities only on the fishing grounds off Shag Rocks. The curve obtained (Figure 14) resembled in its middle and final part a typical selectivity curve. It was characterized by a gentle sloping towards the X-axis. It reached a 100% retention factor for fish with a length of 54 cm. Because of such a shape of the selectivity curve for Patagonian toothfish, selectivity interval was relatively wide (8.1 cm). A 50% selection level was reached for relatively small fish (with a length of 34.4 cm). Selectivity coefficient F_s was 2.81, and selection quality coefficient W_s = 0.64. Both of them did not give a high appraisal of the selective properties of the tested material for Patagonian toothfish.

Changes of material properties of the twine codend

Material properties of the twine codend were very good as regards the ability to maintain constant mesh size during its use. Before use, wet mesh size was 123.6 mm, after the first two and after 30 hours of the codend exploitation its mesh size remained the same - 122.4 mm. The thickness of the twines did not undergo any changes either during the study and their kinks maintained their size, shape and stability.

4.2.2 Tape codend with a nominal mesh size of 60 mm

The tape codend, code-named "60" in the text, was made from special steelon tapes with a thickness of 3.5 mm and a width of 20 mm. The meshes of this codend were rectangular in shape. Although their size was determined in a different way, a value thus obtained may be believed to be

identical to mesh size of twine netting. During the measurements made, it equalled 62.5 mm dry and 61.9 mm wet. A change in the size of mesh after submerging in water was very slight, which was probably a result of the physico-chemical finish of this codend by means of a water emulsion of polyurethane resin and its drying at a temperature of 140°C.

During the study, the codend rigging was slightly changed. At the beginning, the codend and the cover were encircled by 4 thick (Ø = 30 mm) splitting straps connected by heavy shackles (Figure 5). After the changes, the 4 straps remained open, holding on to the bottom part of the codend by only two rings (Figure 6). Thus, the fine-meshed liner could easily float above the codend, which, according to the author, improved selection properties of the construction tested. The detailed description of the influence of the rigging upon the selective properties of the codend will be presented on the example of bumphead notothenia.

This codend was tested on the following fishing grounds : Elephant Island, Joinville Island, Shouth Shetland Islands, Palmer Archipelago and Biscoe Archipelago. The main species taken included : spiny icefish (Chaenodraco wilsoni), ocellated icefish, mackerel icefish, Scotia Sea icefish, bumphead notothenia and Notothenia kempi.

Mackerel icefish

The shape of the selectivity curve (Figure 15) corresponded quite well to a theoretical selectivity ogive. It was characterized by a sharp ascent in the area of relatively small length classes of fish. A 50% selectivity level was achieved for fish with a length of 22.2 cm. Full retention was obtained for fish with a length of 33 cm. The selectivity interval was 3.6 cm. Selectivity coefficient F_s was 3.63, and selection quality coefficient W_s was 0.67. Although both coefficient values were not too high, they nevertheless signified a positive appraisal of the selectivity of this net material in the case of mackerel icefish.

Bumphead notothenia

For the analysis of the "60" tape codend selectivity for bumphead notothenia, 14 tows were selected, including 9 made with the codend equipped with 4 splitting straps and 5 made without them. Separate selectivity ogives were drawn for each of the two phases of the experiment (Figure 16).

The analysis of both ogives led to the conclusion that the alterations made in the codend gear increased its selective properties, which could be seen in the increase of fish length for the 50% selectivity level from 20.2 to 21.1 cm and the decrease of selection interval by about 20%. That is why a modernized codend version without straps was used for further selectivity investigations. For this second codend version, the selection interval equalled 4.0 cm, selection coefficient F_s = 3.45, and selection quality W_s was 0.7. The length of fish wholly retained by the codend was 30 cm. The parameters thus obtained gave a general appraisal of the selective capability of the codend with respect to bumphead notothenia at an average level which was connected with too small a mesh of this codend; as a result, a low value of length of fish, the 50% selection level, was obtained.

Scotia Sea icefish

The shape of the curve presented in Figure 17 departs greatly from a typical selectivity ogive. It seems that this was caused by the small amount of material collected, especially as regards smaller length classes. Eight tows in which this species was quite abundant happened to be small tows, as in larger ones, the percentage share of Scotia Sea icefish was negligible. Under these conditions, a broken line was used to show the hypothetical continuation of the ogive. For both the actual and hypothetical ogives, a 50% selection level covered the class of very small fish with a length of 19.2 cm for the true curve and 20.2 cm for the hypothetical one. Selection interval was 2.4 cm, and the length of fish fully retained by the codend - 32.0 cm. Selectivity coefficient F_s = 3.14

and selection quality coefficient W_s was 0.6. These values give an appraisal of this codend's selectivity at a level below average. It may be said that the selectivity of the "60" tape codend for Scotia Sea icefish was much worse than for other Antarctic fish species.

Spiny icefish

Seven tows selected for analysis were characterized by a relatively large yield and short duration. The characteristic feature of the selectivity curve (Figure 18) is the narrow selection interval, equalling 1.7 cm. Unfortunately, it covers very small fish: a 50% selectivity level was determined for fish with a length as small as 17.6 cm. Beginning with a length of 31 cm, fish were fully retained by the codend. Selectivity coefficient F_s was 2.88 and selection quality coefficient W_s = 0.6. It seems that the selection parameters obtained were mostly influenced, apart from the shape of fish, by their length composition in the stock under study, high yield, and short tow duration. Small fish packed together with a large number of larger fish did not have a chance to get near the net material and escape although in theory they should have been able to do so with ease. Under these conditions, the length of fish for the 50% selection level could have been underestimated.

Ocellated icefish

Five tows selected for the study were all characterized by not too large yields. The main species caught in these tows was spiny icefish.

The curve (Figure 19) resembles a theoretical selectivity ogive. It is characterized by a relatively narrow selection interval equalling 2.0 cm. A 50% selection level comprised fish with a length of 28.8 cm. Selectivity coefficient F_s was 4.71, and selection quality coefficient W_s = 0.90. The length of fish retained by the codend in 100% of cases was 32.0 cm. All parameters obtained for ocellated icefish resulted in an exceptionally favourable appraisal of selective capabilities of the "60"

tape codend. It seems that the ability of fish to pass through the meshes in this experiment was very good, and this might have had its influence on the selective properties of the codend tested unlike in the case of spiny icefish, for which conditions of correct selection were unfavourable.

Notothenia kempi

A selectivity ogive is presented in Figure 20. The selection interval for Notothenia kempi was 3.8 cm. A 50% selection level was achieved by the codend for fish with a length of 20.4 cm. Selectivity coefficient F_s was 3.30, and selection quality coefficient was W_s was 0.64. The length of fish fully retained by the codend was 32.0 cm. The above values give a modest appraisal of the "60" tape codend's selective capabilities for Notothenia kempi. The mesh size in the codend was too small to efficiently protect immature fish against capture.

Material properties of the "60" tape codend

Changes in the mesh size in the "60 " tape codend are presented in Table 6. It appears from these measurements that the mesh size was the same during the trawl use and that is why the value of 60 mm was assumed as the mesh size for calculation of selectivity parameters.

4.2.3 Tape codend with a nominal mesh size of 100 mm

This codend, code-named "100" in the text, had a similar structure to that of the "60" codend, the only difference being that the "100" codend did not have the physico-chemical finish. This codend was tested on the following fishing grounds : South Georgia, South Orkney Island, South Shetland Islands and Elephant Island.

Mackerel icefish

Curves for the South Orkney Islands and for the South Shetland Islands and Elephant Island fishing grounds (Figure 21) were similar in shape and represented the same type of selection. In fact, they constituted the middle and final part of a typical selectivity ogive, which was connected with the occurrence at these grounds of mackerel icefish with lengths exceeding 30 cm. Selection interval was similar for both areas, equalling 7.0 cm on the average. Mean length of mackerel icefish for the 50% selection level could also be assumed as identical for both areas; it equalled 33.5 cm. Under these circumstances selectivity coefficient F_s was 3.3. Selection quality coefficient could also be assumed as identical for both curves : W_s = 0.72. The length of fish fully retained by the codend was 47.0 cm. The data obtained allow for a favourable appraisal of the "100" tape codend's selectivity for mackerel icefish.

Bumphead notothenia

Selectivity curves for the three investigated areas (Figure 22) had a similar shape, corresponding rather well to a standard selectivity ogive. The following values of basic selectivity parameters of the codend tested for fish caught at South Georgia grounds were determined on the basis of the analysis of these ogives : selection interval - 5.4 cm, mean length of fish for the 50% selection level - 35.7 cm, selectivity coefficient F_s = 3.51, selection quality coefficient W_s = 0.83, length of fish fully retained by the codend - 43.0 cm. On the basis of these parameters, it may be said that the selectivity of the codend for bumphead notothenia was relatively good.

The values of the basic selectivity parameters for bumphead notothenia taken on South Orkney and South Shetland grounds were similar. They were the following : selection interval - 10.7 cm, mean length of fish for the 50% selection level - 29.8 cm, selectivity coefficient F_s = 2.43, selection quality coefficient W_s = 0.75. Parameters obtained were slightly worse than those for bumphead notothenia from South Georgia fishing grounds.

These data clearly confirmed that selectivity depends not only on the material properties of the codend itself but also on many other factors, the most important of them being the yield attained, tow duration, species composition of tow, and the length composition of fish in the stock exploited. That is why the same codend may get seemingly different appraisals as regards its selectivity properties for the same species of fish, depending on the exploitation conditions, in which it is being used.

Scotia Sea icefish

During the study period, only on the South Georgia fishing gounds, material suitable for the analysis of the codend for Scotia Sea icefish was collected in 5 tows.

The analysis of the selectivity ogive (Figure 23) made it possible to determine the following values of basic selectivity parameters : selection interval - 14.2 cm, mean length of fish for the 50% selection level - 24.2 cm, selectivity coefficient F_s = 2.38, selection quality coefficient W_s = 0.49, length of fish fully retained by the codend - 49.0 cm. The values thus obtained signified that selective properties of the codend with respect to Scotia Sea icefish were unsatisfactory. This was seen in a tendency of the codend to retain a large number of relatively small specimens. It is possible that the unfavourable results were influenced by the presence of various bottom organisms taken together with Scotia Sea icefish as well as the lack of physico-chemical finish of the codend.

Ocellated icefish

Selectivity ogives were drawn for the two fishing grounds (Figure 24). The shape of both curves was almost identical. It must be stressed, however, that in both cases the number of specimens in the classes of smaller fish having a strong influence on the shape of the curve, was exceptionally low. That is why a more detailed analysis will deal only

with the curve for South Orkney Island, where fish were diversified in length. The main selectivity parameters for Scotia Sea icefish caught on the South Orkney fishing grounds were the following : selectivity interval - 2.3 cm, mean length of fish for the 50% selection level - 26.8 cm, selectivity coefficient F_s = 2.67, selection quality coefficient W_s = 0.69, length of fish fully retained by the codend - 39.0 cm. The values of these parameters estimate selective properties of this codend at a moderate level. The value of selectivity coefficient is especially low. However, taking into account the possibility of improving the codend's material properties, one may hope that it will be later given a favourable estimate, after a new set of data for the corrected versions has been collected.

Spiny icefish

Spiny icefish was found in greater numbers only on the South Shetland fishing grounds. During the study it was possible to select only one tow, very abundant, in which 8.2 tons of fish, mostly spiny icefish were taken. The tow duration was relatively short. Most fish were quickly packed together in the codend and it may be expected they did not have a chance to escape through the meshes. Thus, despite the great number of fish measured (Table 5) the above reservations should be borne in mind when interpreting the data obtained in this experiment.

The selectivity ogive drawn on the basis of measurements and calculations made is presented in Figure 25. This curve served as a basis for the calculations of the following main selection parameters of the codend for spiny icefish : selectivity interval - 2.7 cm, mean length of fish for the 50% slection level - 22.0 cm, selectivity coefficient F_s = 2.17, selection quality coefficient W_s = 0.65, length of fish fully retained by the codend - 34.0 cm. It could be expected that due to circumstances described above, i.e. the difficult escape of fish through the codend material, the values estimating selectivity will have relatively low values, reflecting a negative appraisal of this codend's selectivity. This appraisal, however, must be related to a given experiment. It seems that when its conditions change and a situation favouring the correct

process of fish selection is created, it will remain at the same level as was the case with ocellated icefish. It is clear that in case of such abundant catches, when within a short time tons of fish enter the codend, it is difficult to speak about selectivity as such.

South Georgia icefish

This species occurred in greater quantities only on the fishing grounds of South Georgia. A characteristic feature of the material collected was the small number of specimens with lengths below 25 cm and the absence of fish in certain length classes, e.g. 26-29 cm. Larger fish were represented in greatest numbers. On the basis of measurements and calculations made, a selectivity ogive for South Georgia icefish was drawn (Figure 26).

As a result of the analysis of selectivity of the big tape codend for South Georgia icefish, the following values of main selection parameters were obtained : selection interval - 8.5 cm, mean length of fish for the 50% selection level - 23.0 cm, selectivity coefficient F_s = 2.26, selection quality coefficient W_s = 0.58, length of fish fully retained by the codend - 40.0 cm. These parameters give a negative appraisal of the codend. It seems, however, that the collection of more numerous material and an improvement of material properties of the codend would improve this appraisal.

Material properties of the "100" tape codend

The mesh size of the "100" tape codend changed during the trawl use in the manner presented in Table 7.

Although the changes in mesh size were not great, the tape net material could hardly be classified as stable. Mesh size changed because of the unstable tape junctions.

CONCLUSIONS

The value of main selection parameters for each type of codend for selected fish species are listed in Table 8. Our trawl selectivity studies were conducted for the first time in the Antarctic and that is why the mesh size of net materials from which codends were made was not selected well. During the experiment two different constructions were appraised unfavourably : double-layer codend and single-layer codend, made of twine and having a similar selectivity characteristic for several commercial fish species taken in the Antarctic. The mesh size in these codends (120 mm) turned out to be too big for almost all species of Antarctic fish studied. This net material may be used in practice only for Patagonian toothfish.

Data collected during selectivity studies for both tape codends seemed quite interesting. It was demonstrated that net materials of this type had selective properties and may be used in practice for the construction of codends used for the capture of Antarctic fish. Unfortunately, none of the tested mesh sizes may be recommended for practical use because one of them, 60 mm, was too small for most fish species while the other, 100mm, was too large. The positive impact of a change of mesh size from 60 to 100 mm on an increase in fish length for the 50% selection level and the length of fish fully retained by the codend was noted during the tests with both tape net materials. An increase in mesh size also brought about an increase in selection interval, which may have been connected with the different physico-chemical finish of both tape materials, and increase in the selection quality coefficient though there were exceptions to this rule. It was most difficult to interpret changes in selectivity coefficients because for some fish species, e.g. bumphead notothenia and mackerel icefish, this coefficient did not change significantly while for others it decreased, which should be related to a deterioration of the codend material properties.

The experiments indicated that the protection of juvenile Antarctic fish is possible by the choice of proper mesh size in the codend. The results obtained, however, should be treated as preliminary. Selectivity studies of codends used in the Antarctic should be continued with

additional mesh sizes of 70 and 80 mm in the codends with a very fine physico-chemical finish. Further studies should also take into account the observed different behaviour of fish in the codend, their number and length composition, amount and species composition of the by-catch and other factors. It turned out that these conditions may considerably influence the selectivity of codends.

Table 1 : Characteristics of codend net materials

Type of codend		Materials used for construction					Mesh bar length dry (mm)		Mesh size dry (mm)
		Staple product	Final or width	Thickness of (mm)	Technology chemical production	Physico- finish	Nominal	Actual	
single-layer		polyamide	double twine	Ø 7.0	tied	factory made	80	84	124
		steelon	tape	3.5 x 20	braided	polyurethane	36x25	36x25	61
		steelon	tape	3.5 x 20	braided	no finish	-	-	102
double-layer	outer chafer	steelon	twisted rope	Ø 10	braided	no finish	120	119	220
	codend	steelon	double	Ø 3.5	tied	osolan S	57	59	125

Table 2 : Material for selectivity studies of a double-layer codend (mesh size 120 mm)

Species	Fishing Ground	No of tows	No of fish measured in codend	in liner
Mackerel Icefish	South Gerogia and Shag Rocks	6	430	421
	South Orkney Is.	4	2 272	1 905
Bumphead notothenia	South Georgia and Shag Rocks	9	1 898	979
	South Orkney Is.	6	6 562	2 288
Scotia Sea icefish	South Georgia	9	1 008	325
	South Orkney Is.	3	164	36

Table 3. Material for selectivity studies of a single-layer twine codend (mesh size 120 mm)

Species	Fishing Ground	No of tows	No of fish measured in codend	in liner
Mackerel icefish	South Georgia	9	2 864	2 274
	South Shetland Is.	8	3 501	1 084
	Elephant I.			
Bumphead notothenia	South Georgia	7	1 663	1 093
	South Shetland Is.	8	10 609	4 253
	Elephant I.			
Scotia Sea icefish	South Georgia	7	3 490	1 161
	South Shetland Is.	7	827	106
	Elephant I.			
Ocellated icefish	South Shetland Is.	7	4 901	153
	Elephant I.			

Table 4. Material for selectivity studies of a single-layer tape codend (mesh size 60 mm) collected in the Antarctic Peninsula area.

Species	No of tows		No of fish measured	
	codend with straps	without straps	in codend	in liner
Mackerel icefish	7	-	10 809	82
Bumphead notothenia	9	-	4 424	2 706
		5	3 776	1 160
Scotia icefish	8	-	523	42
Spiny icefish	7	-	69 147	379
Ocellated icefish	5	-	742	130
Notothenia kempi	5	-	1 190	778

Table 5. Material for selectivity studies of a single-layer tape codend (mesh size 100 mm)

Species	Fishing Ground	No of tows	No of fish measured in codend	in liner
Mackerel icefish	South Orkney Is.	3	10 615	2 771
	South Shetland Is.	3	1 687	454
	Elephant I.			
Bumphead notothenia	South Georgia	5	795	1 156
	South Orkney Is.	3	1 178	1 059
	South Shetland Is.	3	2 670	3 826
	Elephant I.			
Scotia Sea icefish	South Georgia	5	1 646	1 272
Ocellated icefish	South Orkney Is.	3	1 263	50
	South Shetland Is.	3	2 386	56
Spiny icefish	South Shetland Is.	1	36 400	5 856
South Georgia Icefish	South Georgia	5	560	62

Table 6 : Changes in the mesh size (mm) in the "60" tape codend

After first tow	After 20 hours	After 40 hours	After 60 hours	Mean
61.8	60.7	61.0	61.9	61.2

Table 7 : Changes in mesh size of the "100" tape codend

Value measured	Before use		After 2 hours	After 10 hours	After 25 hours	Mean assumed for calculation
	Dry	Wet				
Mean (mm)	98.0	100.9	101.1	101.1	102.0	101.6

Table 8. Values of main selectivity parameters of codends tested

Type of codend selectivity parameter	Double-layer codend			single-layer codends															
				twine			"60" tape							"100" tape					
	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Ocellated icefish	Patagonian toothfish	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Spiny icefish	Ocellated icefish	Notothenia kempi	Mackerel icefish	Bumphead notothenia	Scotia Sea icefish	Ocellated icefish	Spiny icefish	South Georgia icefish
Selectivity interval	–	very wide	very wide	–	very wide	very wide	1.6	8.1	3.6	4.0	2.4	1.7	2.0	3.8	7.0	5.4	14.2	2.3	2.7	8.5
Length of fish for 50% selection level	·	·	·	·	·	·	27.0	34.4	22.2	21.1	19.2	17.6	28.8	20.4	33.5	35.7	24.2	26.8	22.0	23.0
Selectivity coefficient	·	·	·	·	·	·	2.21	2.81	3.63	3.54	3.15	2.85	4.74	3.30	3.30	3.51	2.38	2.67	2.17	2.26
Selectivity quality coefficient	·	·	·	·	·	·	0.61	0.84	0.67	0.70	0.60	0.60	0.90	0.64	0.72	0.83	0.49	0.69	0.65	0.58
Length of fish fully retained	·	46.0	44.0	51.0	45.0	43.0	44.0	54.0	33.0	30.0	32.0	31.0	32.0	32.0	47.0	43.0	49.0	39.0	34.0	40.0

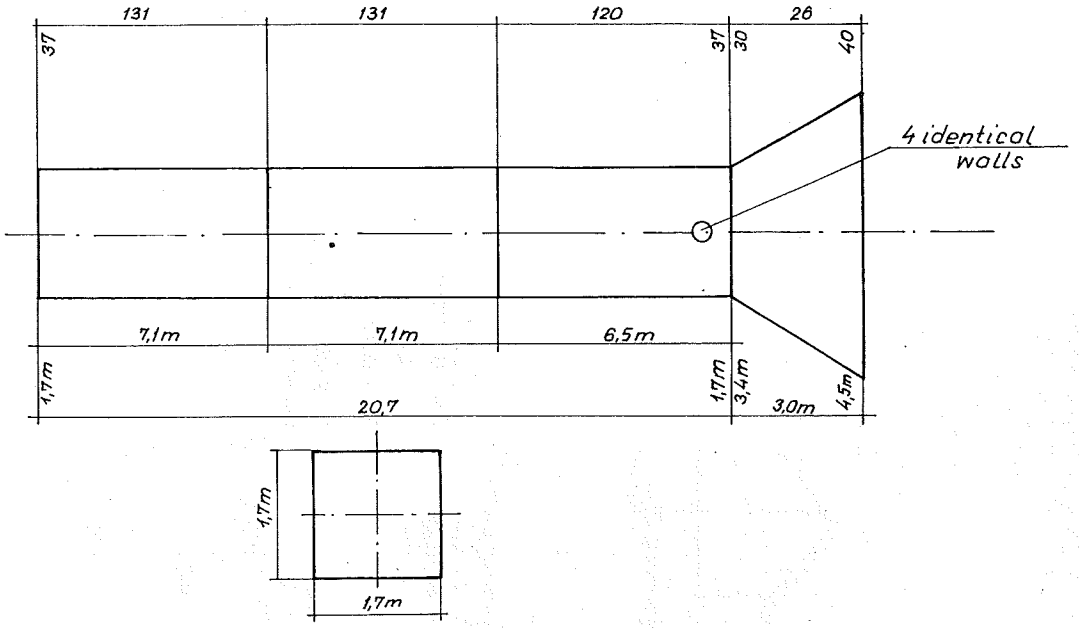


Figure 1 Plan of tape codend construction.

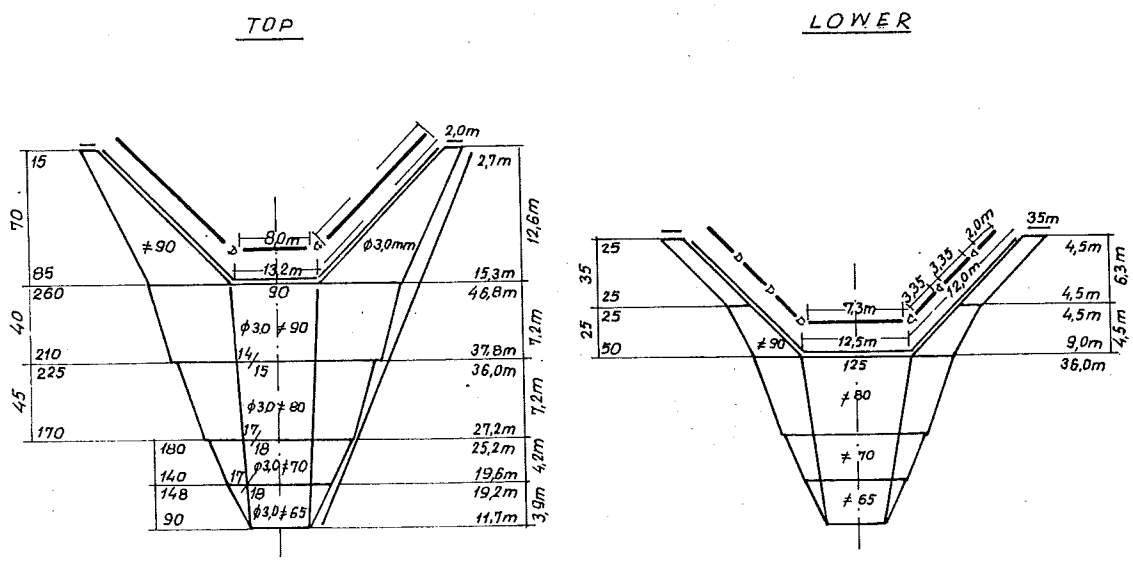


Figure 2 Plan of 32/36 bottom trawl construction.

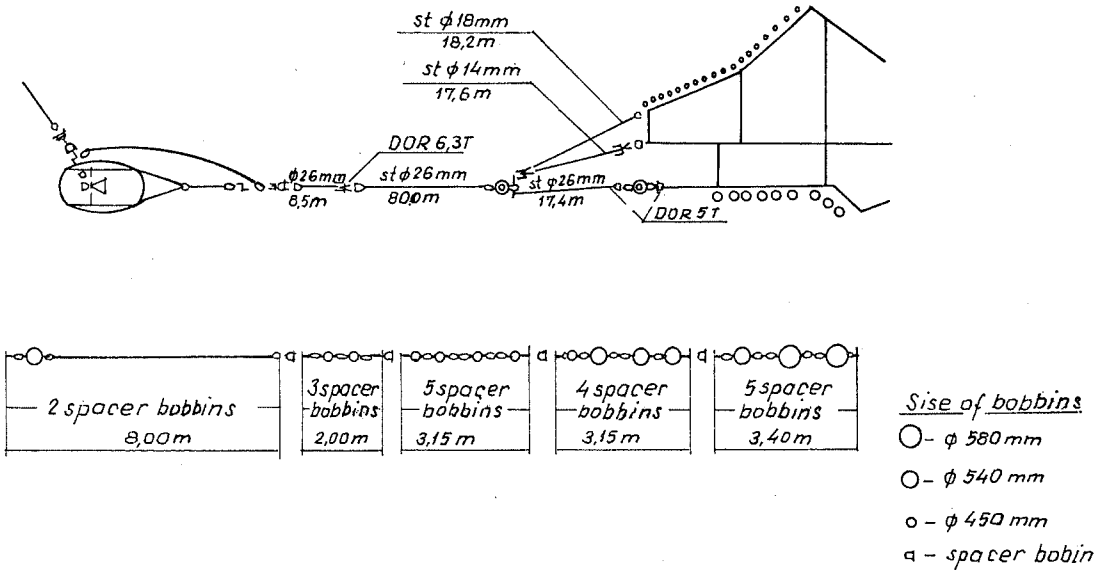


Figure 3 Plan of gear rigging for 32/36 bottom trawl.

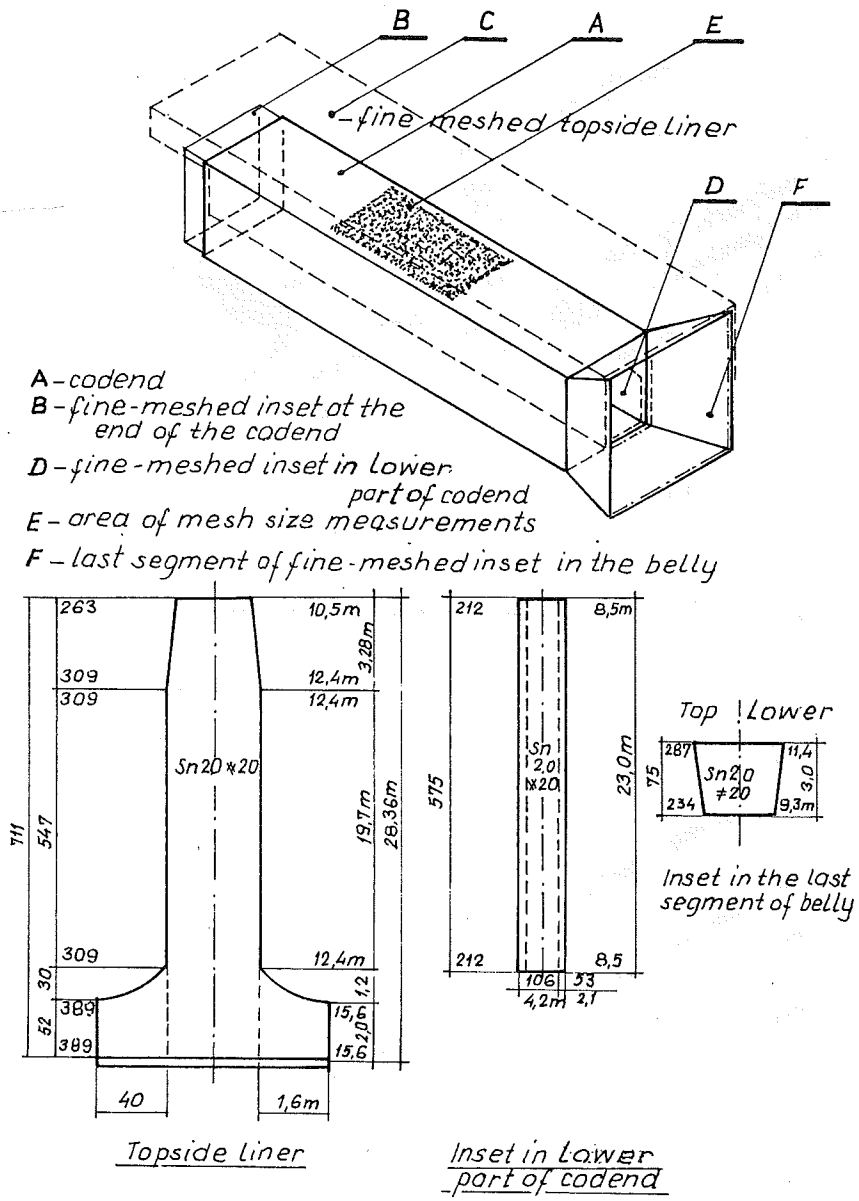
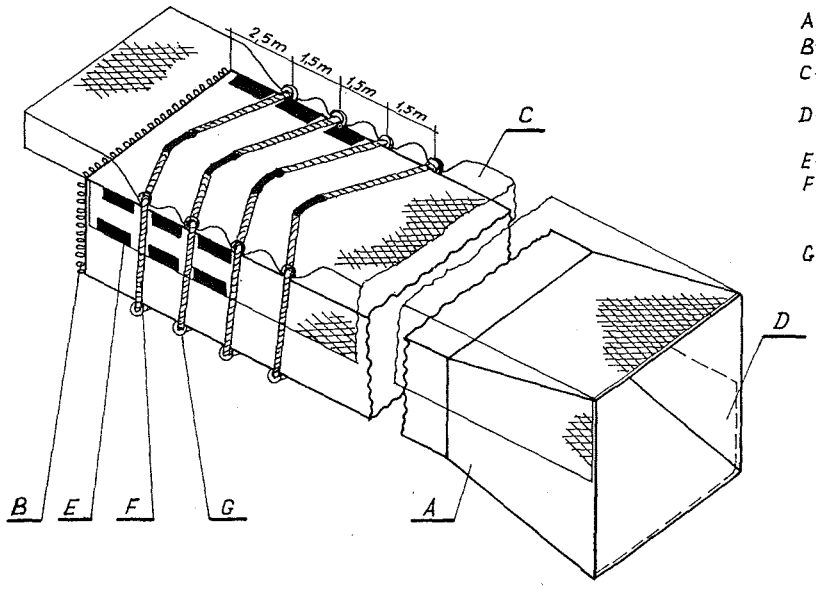
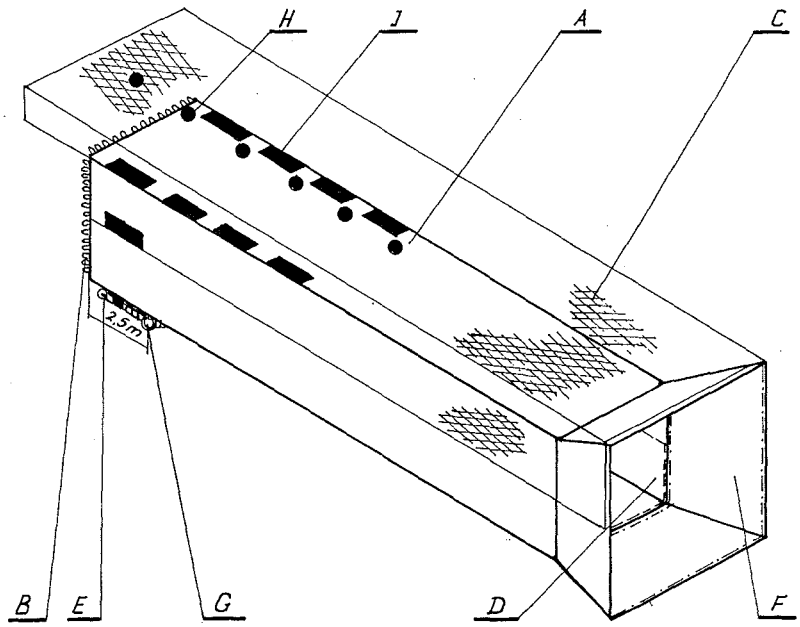


Figure 4 Plan of tape codend with fine-meshed topside liner and fine-meshed inset in lower part of codend.



A-codend
B-kelly's eyes
C-fine-meshed topside liner
D-fine-meshed inset in lower part of codend
E-5 floats ϕ200mm
F-strop; rope ϕ30mm with length of 5m, with rings at their ends
G-steel eye ϕ100mm

Figure 5 Plan of standard codend rigging (version I).



A-codend
B-kelly's eyes
C-fine-meshed topside liner
D-fine-meshed inset in lower part of codend
E-5 floats ϕ 200m
F-fine-meshed inset in the last segment of belly
G-steel eye ϕ100mm
H-float ϕ 200mm placed under netting of topside liner
J-5 floats ϕ 200mm

Figure 6 Plan of modified tape codend rigging (version II).

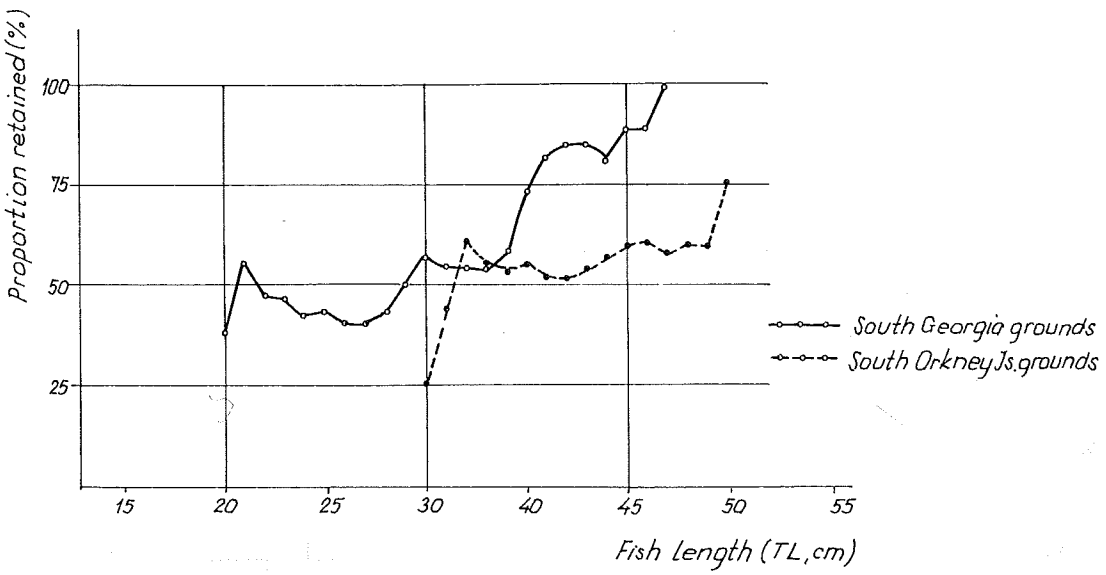


Figure 7 Double-layer codend (mesh 120 mm) selectivity ogive for mackerel icefish.

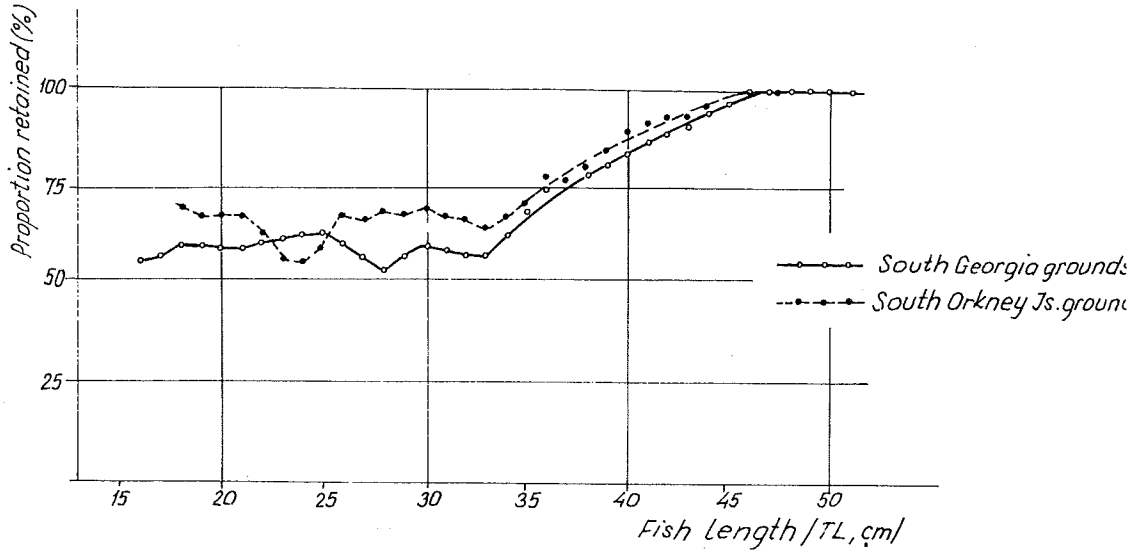


Figure 8 Double-layer codend (mesh 120 mm) selectivity ogive for bumphead Notothenia.

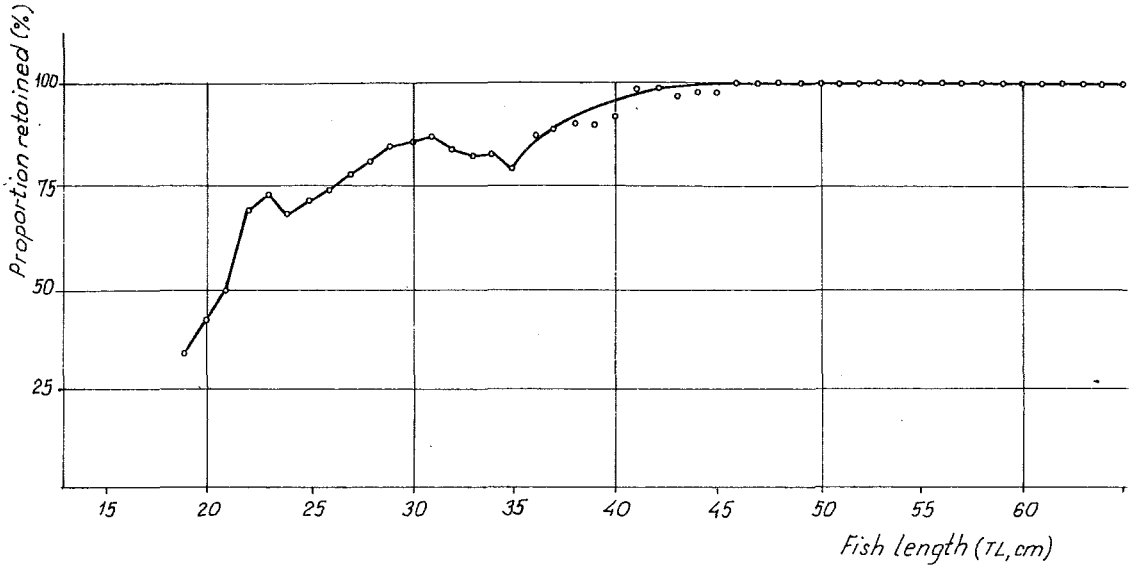


Figure 9 Double-layer codend (mesh 120 mm) selectivity ogive for Scotia Sea icefish on South Georgia grounds.

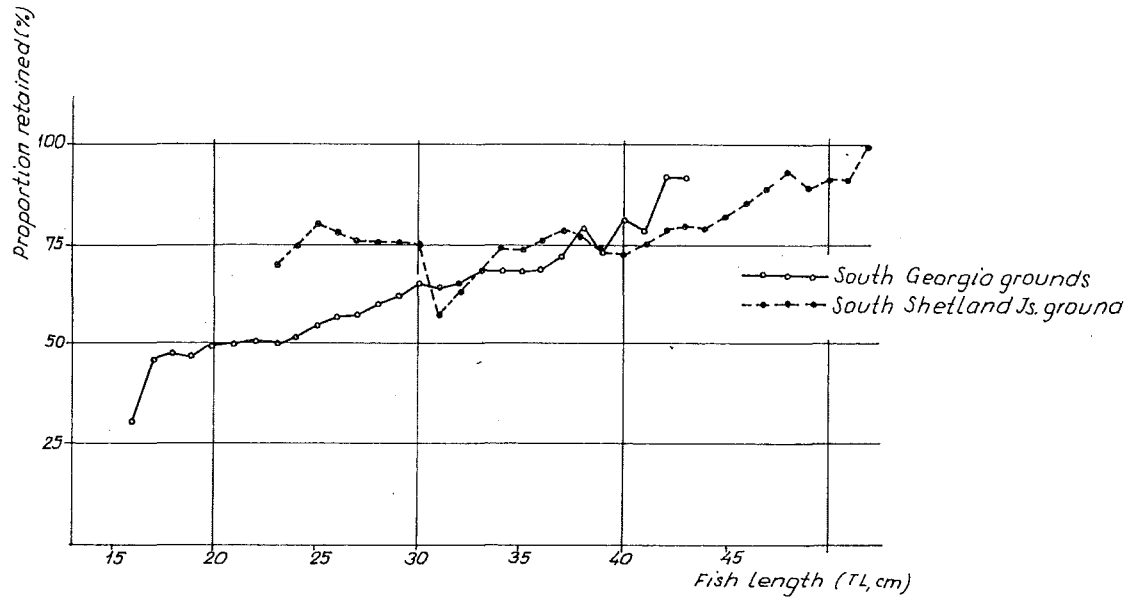


Figure 10 Twine codend (mesh 120 mm) selectivity ogive for mackerel icefish.

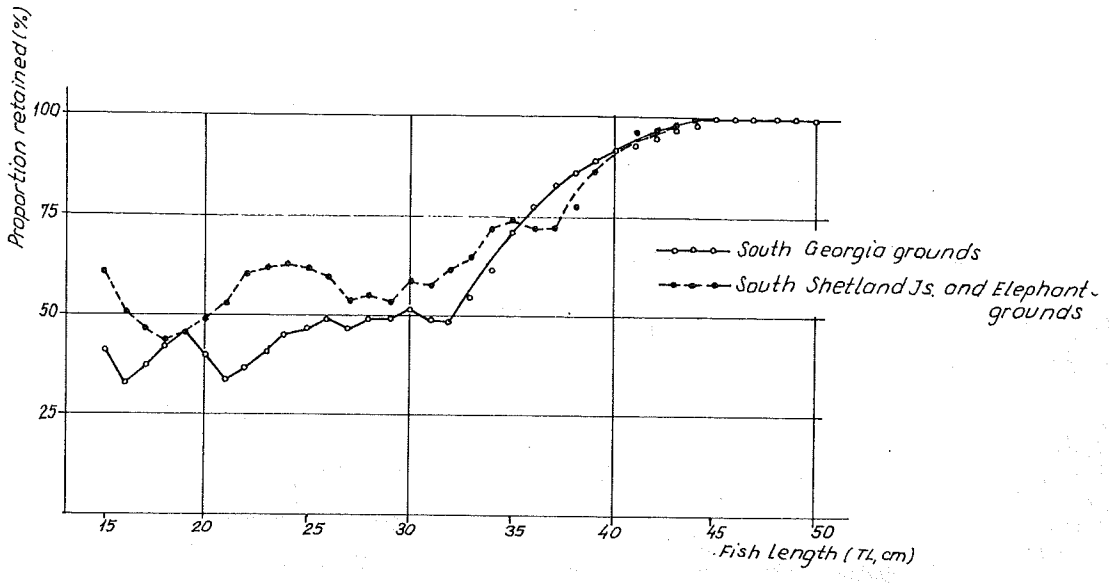


Figure 11 Twine codend (mesh 120 mm) selectivity ogive for bumphead Notothenia.

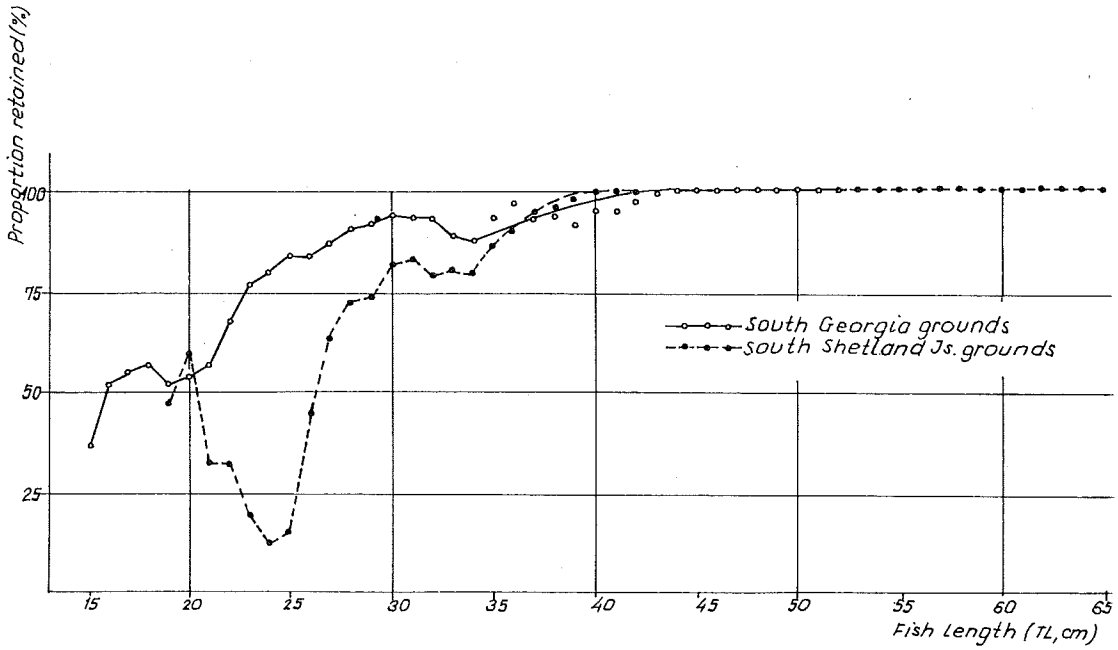


Figure 12 Twine codend (mesh 120 mm) selectivity ogive for Scotia Sea icefish.

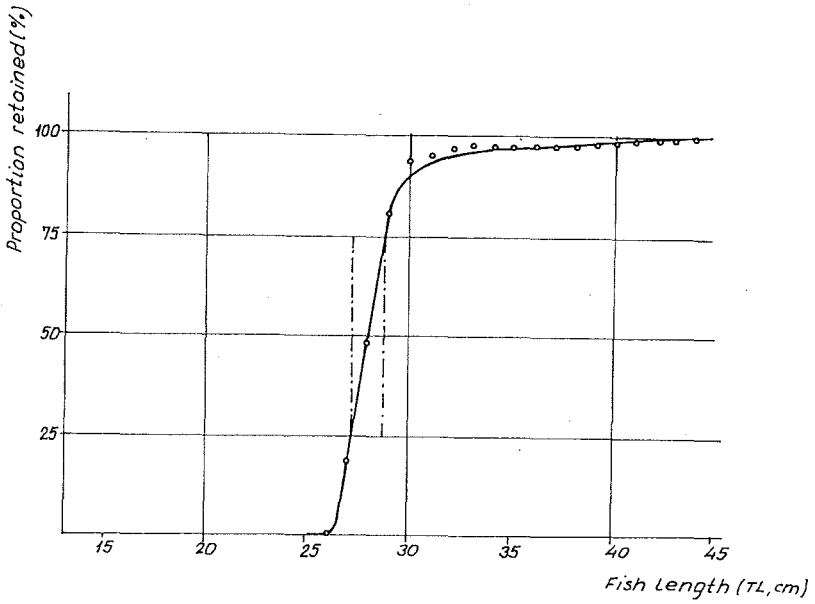


Figure 13 Twine codend (mesh 120 mm) selectivity ogive for ocellated icefish.

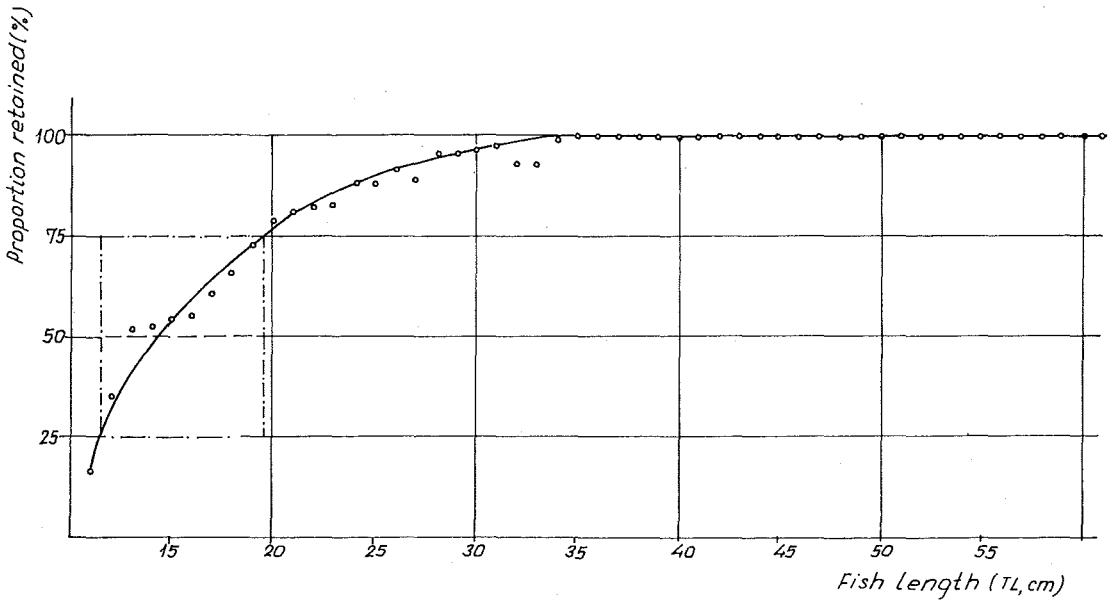


Figure 14 Twine codend (mesh 120 mm) selectivity ogive for Patagonian toothfish.

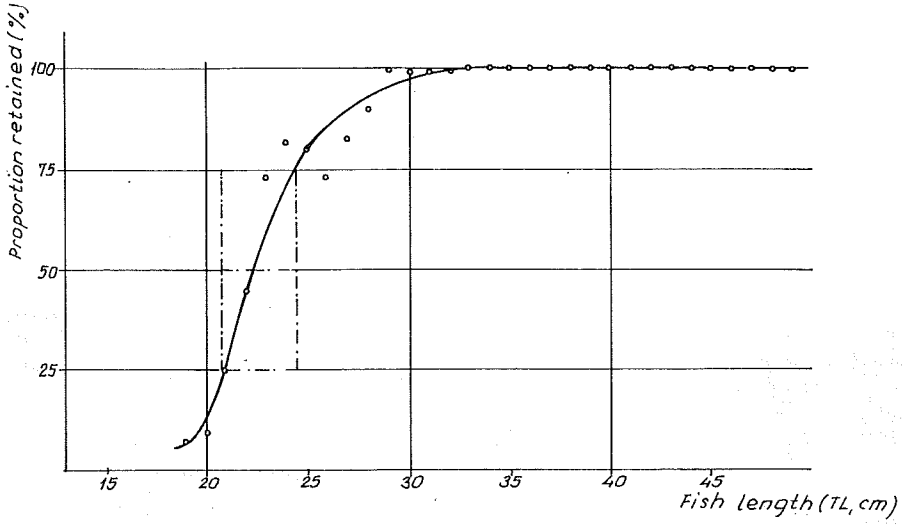


Figure 15 Tape codend ("60") selectivity ogive for mackerel icefish on Antarctic Peninsula grounds.

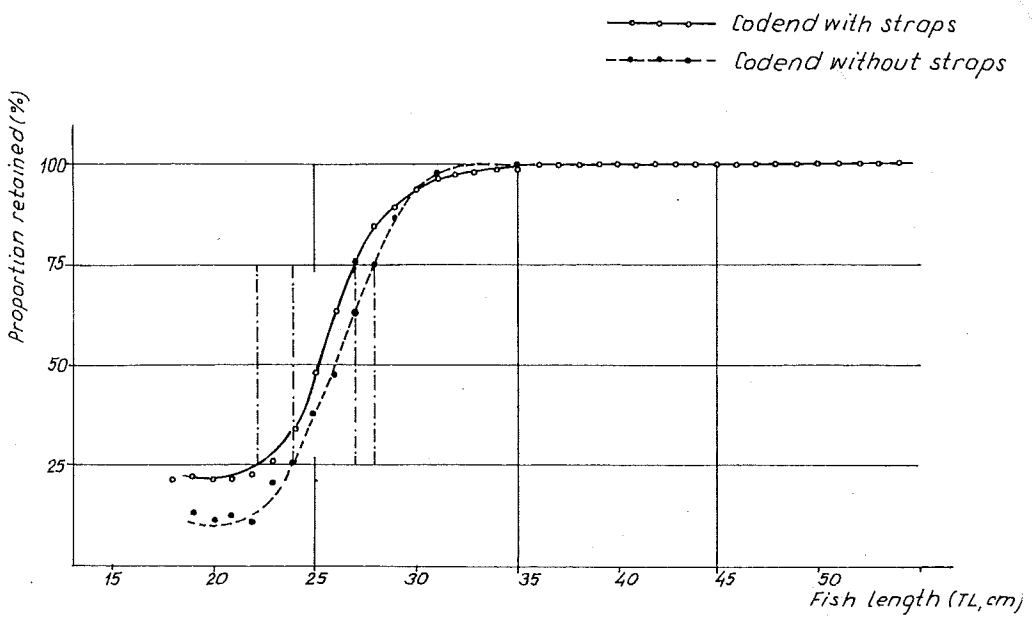


Figure 16 Tape codend ("60") selectivity ogive for bumphead Notothenia on Antarctic Peninsula grounds.

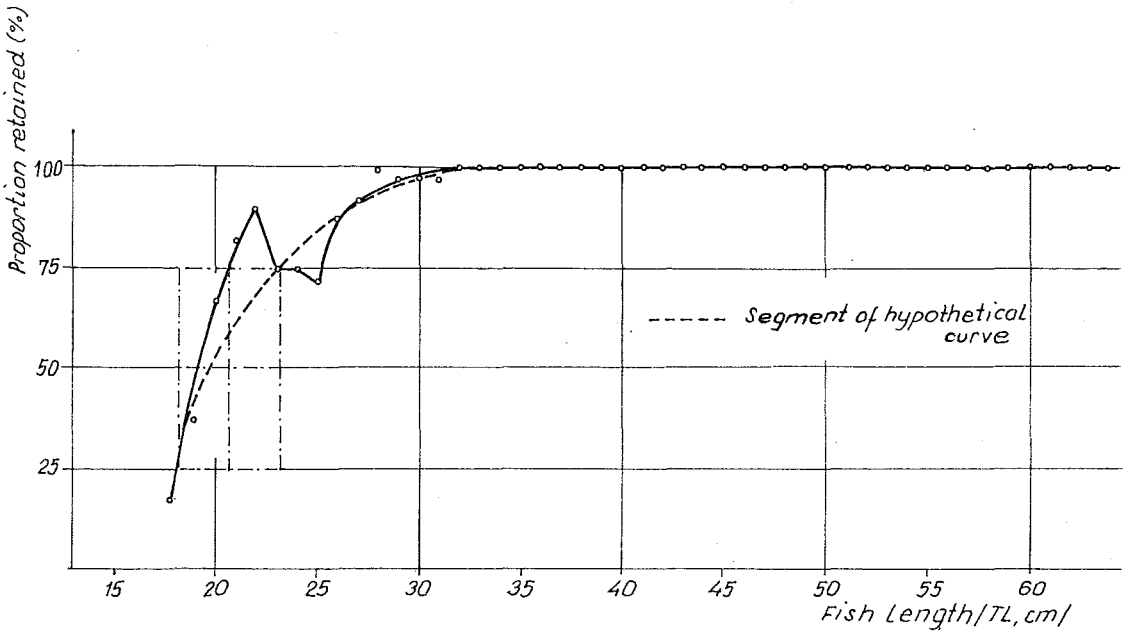


Figure 17 Tape codend ("60") selectivity ogive for Scotia Sea icefish on Antarctic Peninsula grounds.

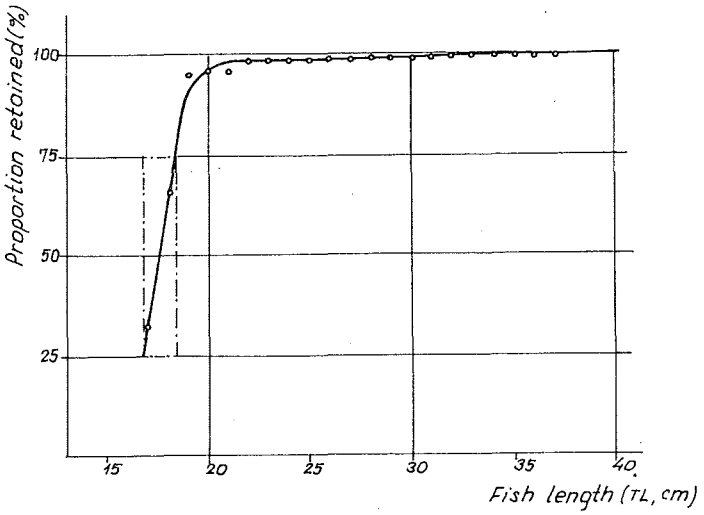


Figure 18 Tape codend ("60") selectivity ogive for spiny icefish on Antarctic Peninsula grounds.

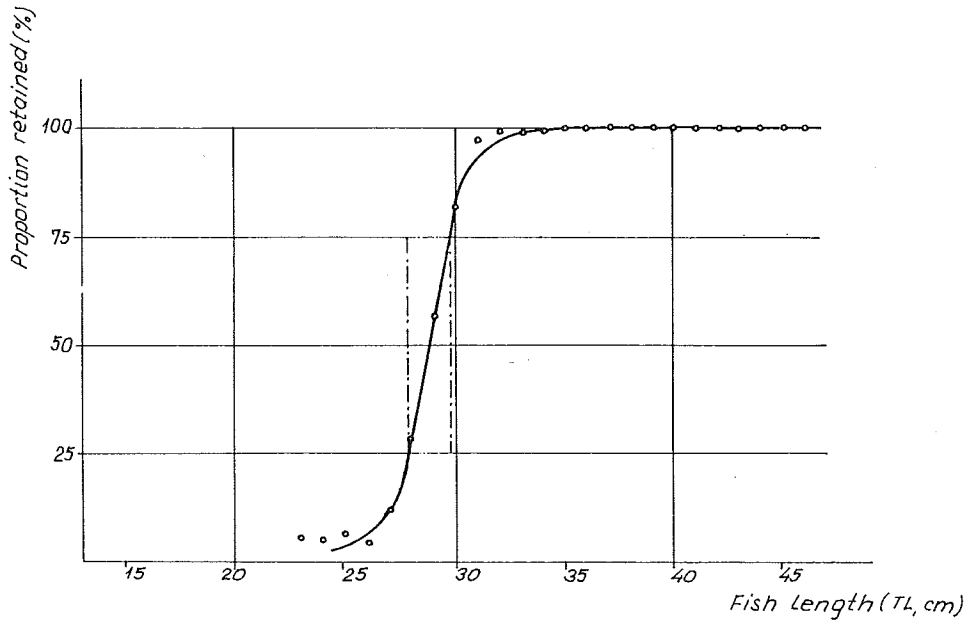


Figure 19 Tape codend ("60") selectivity ogive for ocellated icefish on Antarctic Peninsula grounds.

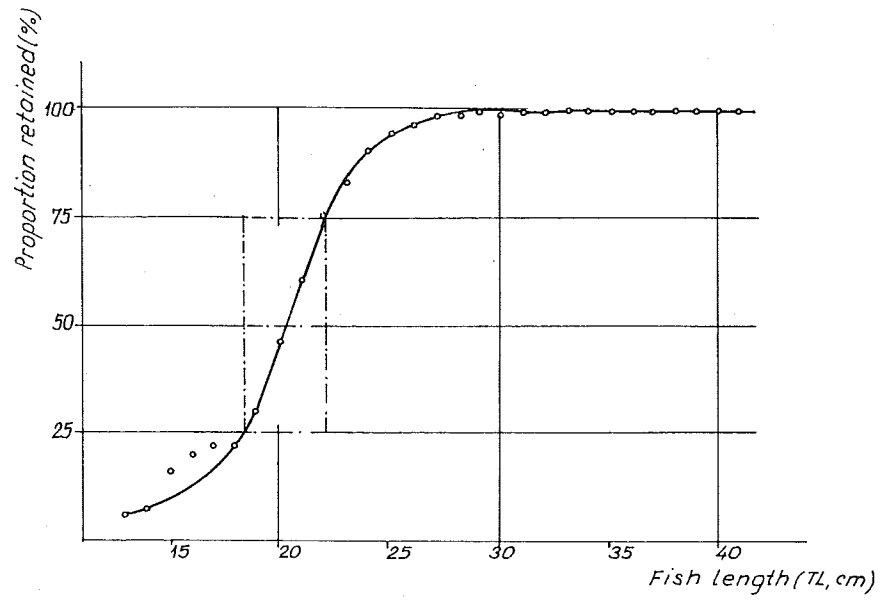


Figure 20 Tape codend ("60") selectivity ogive for Notothenia kempi on Antarctic Peninsula grounds.

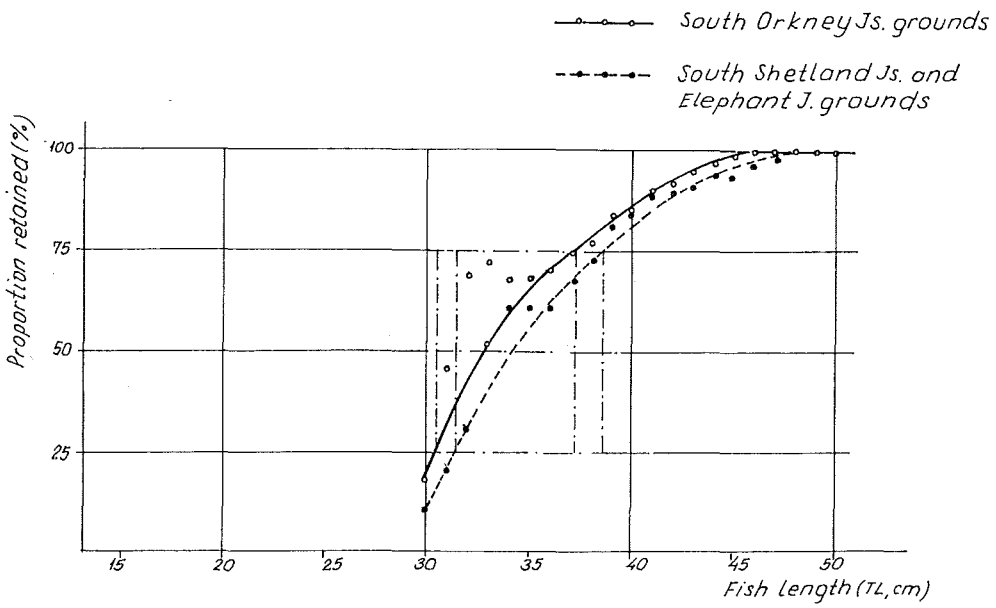


Figure 21 Tape codend ("100") selectivity ogive for mackerel icefish.

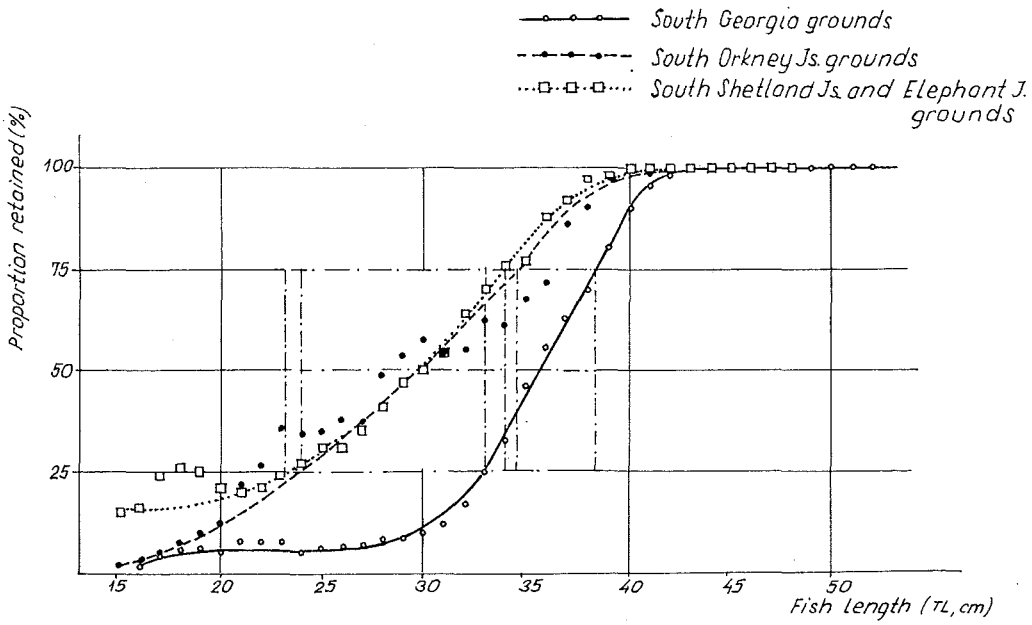


Figure 22 Tape codend ("100") selectivity ogive for bumphead Notothenia.

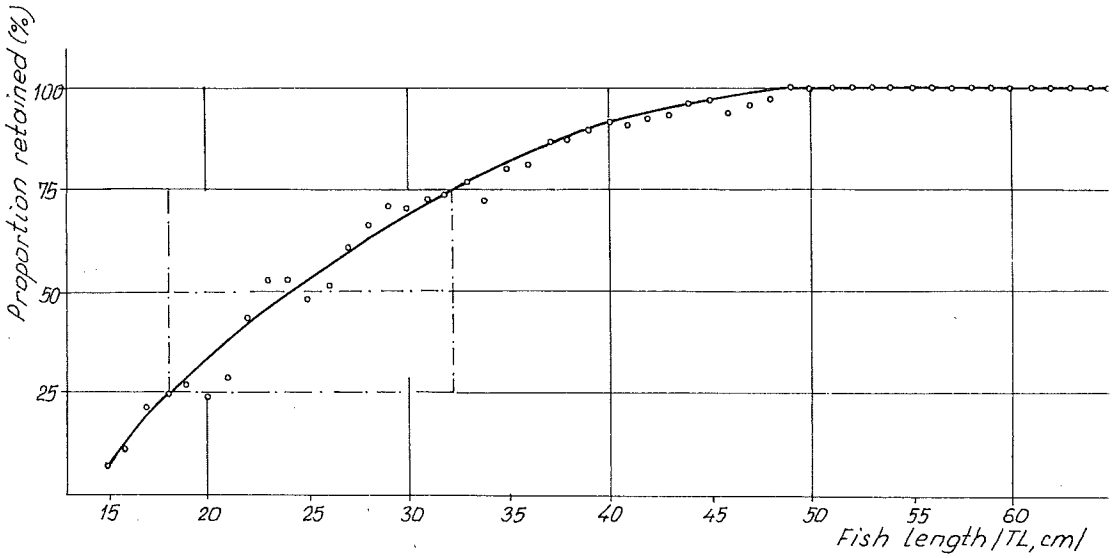


Figure 23 Tape codend ("100") selectivity ogive for Scotia Sea icefish on South Georgia grounds.

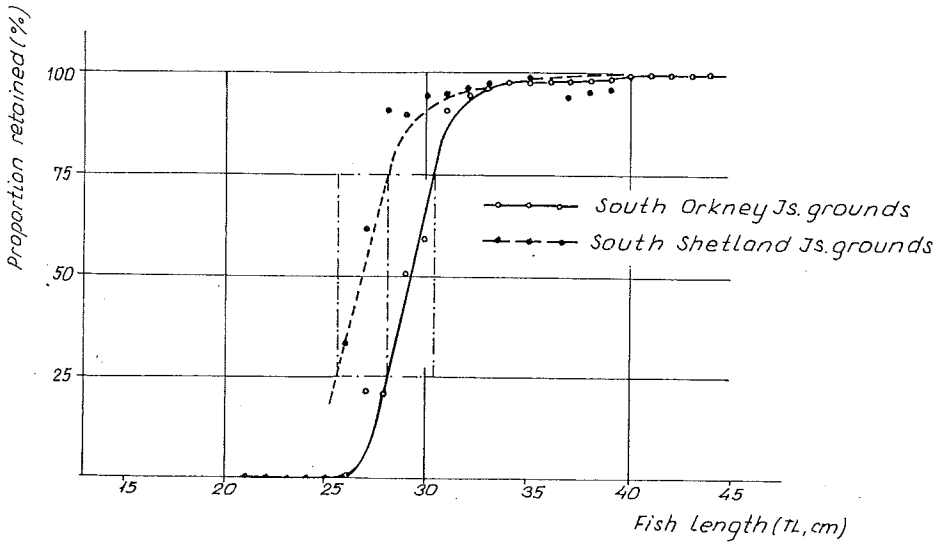


Figure 24 Tape codend ("100") selectivity ogive for ocellated icefish.

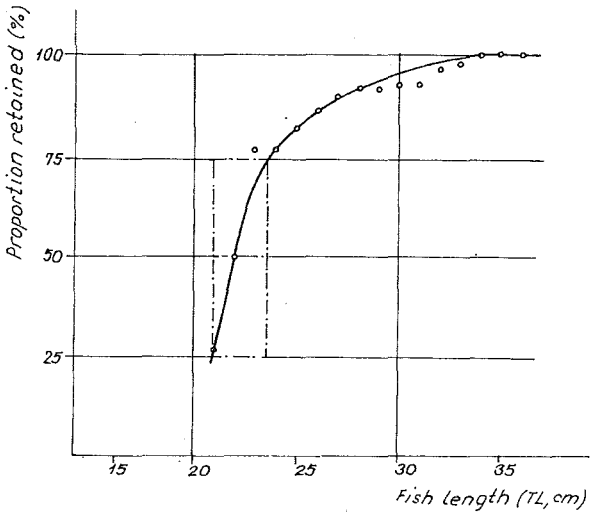


Figure 25 Tape codend ("100") selectivity ogive for spiny icefish on South Shetland grounds.

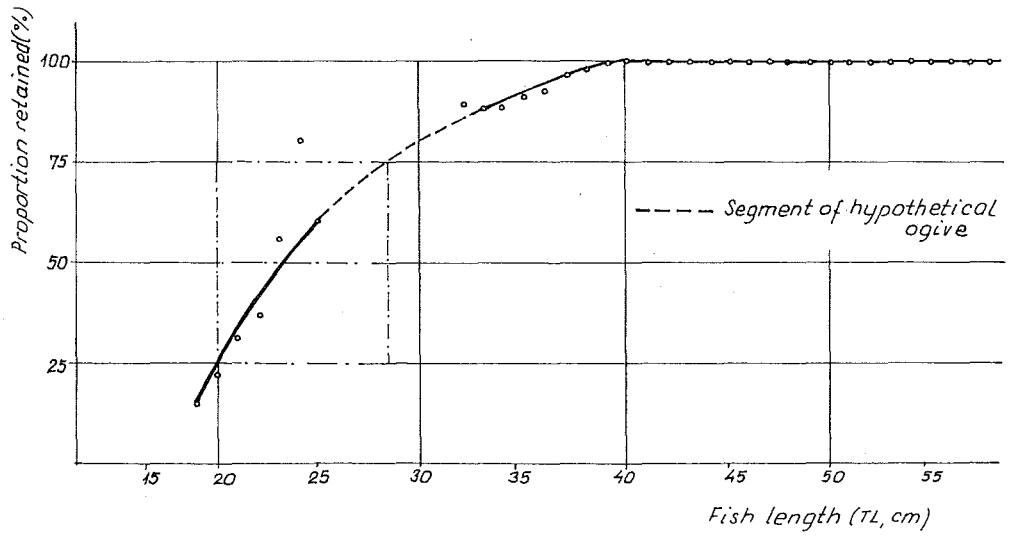


Figure 26 Tape codend ("100") selectivity ogive for South Georgia icefish on South Georgia grounds.

Légendes des tableaux

Tableau 1 Caractéristiques des matériaux du filet au cul de chalut.

Tableau 2 Données pour les études de sélectivité d'un cul de chalut à deux couches (taille du maillage 120 mm).

Tableau 3 Données pour les études de sélectivité d'un cul de chalut à cordes à une seule couche (taille du maillage 120 mm).

Tableau 4 Données pour les études de sélectivité d'un cul de chalut à rubans à une seule couche (taille du maillage 60 mm) recueillies dans la zone de la Péninsule Antarctique.

Tableau 5 Données pour les études de sélectivité d'un cul de chalut à rubans à une seule couche (taille du maillage 100 mm).

Tableau 6 Changements dans la taille du maillage (mm) du cul de chalut à rubans de "60".

Tableau 7 Changements dans la taille du maillage du cul de chalut à rubans de "100".

Tableau 8 Valeurs des principaux paramètres de sélectivité des culs de chalut testés.

Légendes des figures

Figure 1 Plan de la construction du cul de chalut à rubans.

Figure 2 Plan de la construction du chalut de fond 32/36.

Figure 3 Plan du gréement de l'engin de pêche pour le chalut de fond 32/36.

Figure 4 Plan du cul de chalut à rubans avec un voile supérieur à petites mailles et un entre-deux à petites mailles dans la partie inférieure du cul de chalut.

Figure 5 Plan du gréement standard du cul de chalut (version I).

Figure 6 Plan du gréement modifié du cul de chalut à rubans (version II).

Figure 7 Ogive de sélectivité du cul de chalut à deux couches (maillage 120 mm) pour le maquereau des glaces.

Figure 8 Ogive de sélectivité du cul de chalut à deux couches (maillage 120 mm) pour Notothenia gibberifrons.

Figure 9 Ogive de sélectivité du cul de chalut à deux couches (maillage 120 mm) pour Chaenocephalus aceratus sur les secteurs de pêche de la Géorgie du Sud.

Encabezamientos de las Tablas

Tabla 1 Características de los materiales de las redes de corona.

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Заголовки к таблицам

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Таблица 3 Информация для изучения селективности однослойного веревочного кутка (размер ячей - 120 мм).

Таблица 4 Информация для изучения селективности однослойного ленточного кутка (размер ячей - 60 мм), собранная в районе Антарктического полуострова.

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Таблица 6 Изменения в размере ячей (в мм) ленточного кутка "60".

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Рисунок 1 Схема устройства ленточного кутка.

Рисунок 2 Схема устройства донного трала 32/36.

Рисунок 3 Схема оснащения донного трала 32/36.

Рисунок 4 Схема ленточного кутка с мелкоячеистым рыбоуловителем в верхней части и мелкоячеистым вкладышем в нижней части кутка.

Рисунок 5 Схема стандартного монтажа кутка (вариант I).

Рисунок 6 Схема модифицированного монтажа ленточного кутка (вариант II).

Рисунок 7 Огива селективности двуслойного кутка (ячея - 120 мм) для ледяной скумбрии.

Рисунок 8 Огива селективности двуслойного кутка (ячея - 120 мм) для зеленой нототении.

Рисунок 9 Огива селективности двуслойного кутка (ячея - 120 мм) для ледяной рыбы моря Скотия в районе Южной Георгии.

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