SELECTIVITY OF STANDARD POLISH COMMERCIAL TRAWL CODENDS ON ANTARCTIC FISHING GROUNDS

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Abstract

Selectivity studies were carried out for two types of steelon codends used in commercial fishery, with a nominal mesh size A = 80 mm and A = 100 mm, made of double twines with a thickness of 4.2 mm. The studies covered 6 major fish species.

1. It appears from the study that Antarctic icefish and bumphead notothenia are subject to selection during trawling, although the effectiveness of this process - especially in the latter case - is not satisfactory.

2. Scotia Sea icefish, *Chaenodraco wilsoni*, and *Chionodraco rastrospinosus* exhibit a lower tendency to pass through meshes of the codend than Antarctic icefish and bumphead notothenia.

3. The solution to the problem of ensuring selectivity of codends at a sufficiently good level seems possible as a result of the application of webbing with permanently open meshes for codend construction.

4. The most difficult matter will be preparing a codend with proper selectivity properties for South Georgia icefish, because this species exhibits the smallest tendency to escape during the trawling among all the species studied.

Conclusions and observations were in some cases based on a relatively small amount of experimental material.

Further investigations of this problem are necessary since producing selective trawl gear for harvesting Antarctic fish seems crucial from the point of view of conservation of living fish resources on those fishing grounds.

Résumé

Des études sur la sélectivité ont été menées sur deux types de culs de chalut en steelon utilisés dans les pêcheries commerciales, avec un maillage nominal A = 80 mm et A = 100 mm, faits de cordes doubles d'une épaisseur de 4,2 mm. Les études portaient sur 6 majeures espèces de poissons.

1. L'étude montre que les poissons des glaces et les bocasses bossues sont sujets à sélection au cours du chalutage, bien que l'efficacité de ce procédé - particulièrement dans le dernier cas - laisse à désirer.

2. Les grandes-gueules antarctiques, les *Chaenodraco wilsoni* et *les Chionodraco rastrospinosus* ont moins tendance à passer à travers les mailles du raban de cul que les poissons des glaces et les bocasses bossues.

3. Il semble possible de résoudre le problème d'une sélectivité satisfaisante de rabans de cul grâce à l'utilisation d'une sangle à mailles ouvertes en permanence dans la fabrication des culs de chalut.

4. Le problème le plus difficile sera de préparer un cul de chalut ayant les propriétés de sélectivité nécessaires pour la pêche au poisson des glaces de la Géorgie du Sud qui, de toutes les espèces étudiées, est celle qui a le moins tendance à s'évader au cours du chalutage.

Les conclusions et les observations sont dans certains cas basées sur une quantité relativement faible de matériel expérimental.

Il est nécessaire de procéder à d'autres études sur ce problème, la production d'engins de chalutage sélectifs destinés à la pêche des poissons de l'Antarctique paraissant cruciale du point de vue de la conservation des ressources ichtyologiques vivantes dans ces lieux de pêche.

Резюме

Проводились иследования по селективности двух типов применяемых при коммерческом промысле стилоновых кутков с размером ячеи A = 80 мм и A = 00 мм, сделанных из двойного шпагата толщиной 4,2 мм. Исследования охватывали 6 основных видов рыб.

1. Исследования показали, что селекция ледяной рыбы и зеленой нототении происодит во время траления, хотя эффективность этого процесса, особенно в случае зеленой нототении, неудовлетворительна.

2. Крокодиловая белокровка, *Chaenodraco wilsoni* и *Chionodraco rastrospinosus* проявили меньшую тенденцию к прохождению сквозь ячеи кутка, чем ледяная рыба и зеленая нототения.

3. Представляется, что решение проблемы обеспечения достаточно хорошего уровня селективности кутка лежит в использовании при конструировании кутка тетивы с постоянно открытыми ячеими.

4. Самой трудной задачей будет изготовление для селекции темной белокровки кутка с нужными селектывными свойствами, так как из всех изучавшихся видов этот вид во время траления показал наименьшую тенденцию к выходу из сети.

В некоторых случаях выводы и наблюдения сделаны при относительно небольшом количестве экспериментального материала.

Необходимо проведение дальнейших исследований по этому вопросу, так как в плане сохранения живых рыбных ресурсов на этих промысловых участках наиважнейшим представляется конструирование селективных траловых сетей для проведения лова антарктической рыбы.

Resumen

Se realizaron estudios de selectividad con dos tipos de copos de “steelon” que se emplean en la pesca comercial, cuyo tamaño nominal de luz de malla era A = 80 mm y A = 100 mm, hechos con hilo doble de 4,2 mm de espesor. Estos estudios abarcaron seis especies principales de peces.

1. Según dicho estudio, parece que el draco rayado y la trama jorobada están sujetos a selección durante el arrastre, si bien la efectividad de este proceso - especialmente en el segundo caso - no es satisfactoria.

2. El draco antártico, *Chaenodraco wilsoni* y *Chionodraco rastrospinosus* presentan una menor tendencia a pasar por el copo que el draco rayado y la trama jorobada.

3. La solución al problema de asegurar la selectividad a un nivel aceptable parece ser posible aplicando un tejido con las mallas permanentemente abiertas en la fabricación del copo.

4. La cuestión más difícil será preparar un copo con las propiedades de selectividad adecuadas para el draco cocodrilo, ya que, de todas las especies estudiadas, ésta es la que presenta una menor tendencia a escaparse durante el arrastre.

Las conclusiones y observaciones se basaron, en algunos casos, en una cantidad de material experimental relativamente pequeña.

Es necesario investigar aún más este problema, ya que la fabricación de artes de arrastre selectivas para la recolección de peces antárticos parece vital desde el punto de vista de la conservación de los recursos de peces en estas zonas de pesca.

1. INTRODUCTION

Selectivity studies of trawls used by the Polish fishery were conducted in 1950-1980. Cieglewicz and Strzyzewski (1960) studies the mechanism of the passage of cod through various parts of the trawl made of different materials. They came to the conclusion that the main part through which juvenile fish escape is the upper part of the codend. In the 1960's and 1970's extensive investigations of selectivity, directed by Strzyzewski (1971) covered several fish species, taking into account a number of physical factors affecting the selection process, such as choice of material, technological structure of webbing, use of layered structure of material making up the codend, size relations of meshes in the cover and codend, etc. Evaluation of the effect of mesh size and shape on selection of cod in the Baltic was also carried out in the 1970's (Szymanski, 1980). For the first time in Poland, Szymanski used in those studies webbing with permanently open meshes, made of textile belts. It turned out that square, permanently open meshes had the best selectivity properties with respect to cod.

This conclusion was confirmed for other cod-like fish and lobsters by investigations of Robertson (Robertson, 1986a, 1986b). On the other hand, Gabriel, Kemp and Haberstroh (1987) expressed an opinion that the change of mesh shape from rhomboid to square has no special effect on the ratio of undersized fish to landing-sized fish in the codend, but results only in collecting fish less soiled with benthos. It should be emphasized that no attention has been paid in investigations carried out so far to the phenomenon of deferred or arrested reaction of escape of any fish species from the codend.

The first Polish selectivity studies of trawl gear in the Antarctic were carried out in the 1978/79 (Zaucha, 1979) season. It was established during those studies, with the use of, among others, tape codends, that Antarctic fish behave differently during trawling than fish studied before and that it was difficult to interpret the results obtained in an objective and convincing way.

2. OBJECTIVE OF THE STUDY

After the introduction of codend mesh-size regulations in the Antarctic, it was decided that selectivity studies begun in the 1978/79 season would be continued mostly on the basis of codends currently used in commercial fishing operations. The objective of investigations in the 1986/87 season was to determine whether technical and material conditions of codends with a mesh size of 80 mm ensures, from the point of view of the CCAMLR Convention, satisfactory selectivity or whether bottom codends require a certain modification. For comparison, a codend with a mesh size of 100 mm was tested.

3. MATERIALS AND METHOD

Steelon codends with a four-wall, oblique construction made of double steelon twines with a nominal thickness of 4.2 mm were used in the study. Their length was 22.5 m, the square-shaped opening had a side with a length of 6.9 m, while the codend's rectangular tip had sides with lengths of 6.9 x 4.0 m. The codend itself was covered on the outside from the top down to the middle of its height with a cover having relatively small meshes (mesh bar 20 mm). Three sets of floats, 5 in each, were attached to the rear part of the cover. The bottom part of the codend was covered from the inside up to half of the codend's height with a liner made of the same material as the cove. Thanks to such construction of the codend, undersized fish could escape from the codend only from the part equipped with the cover. They were later trapped in the end parts of the cover. Because of difficult conditions on the fishing grounds (stones, rocks, etc.), the codend was protected against mechanical damage by special protective materials placed at its bottom.

A schematic drawing of the codend's construction and construction of the codend proper made of steelon fabric with a nominal mesh size of 80 mm is presented in Figure 1. The codend with a 100 m mesh size had the same construction. In reality both codends had somewhat different mesh sizes than nominal ones, which will be discussed in detail when presenting changes in mesh size during codends use.

The codends used in the selectivity study were used on board the research vessel *Professor Siedlecki* which is a factory trawler with power of 1690 KW (2300 HP). Codends with similar constructions to those used in Polish commercial fishing vessels were included in a 32/31 bottom trawl set-up which was used in previous years on Antarctic fishing grounds and met with positive opinions. A schematic drawing of the construction and rigging of such a setup is presented in Figures 2 and 3.

The process of fish selection by a given codend is characterized by means of a selectivity ogive and a number of additional parameters:

- selectivity interval "Ps": difference in centimetres between the length class of fish retained in the codend in 75% (L_{75}) and the class retained in 25% (L_{25}),

$$Ps = L_{75} - L_{25}$$

- selectivity coefficient "Fs": ratio of the length of this class of fish which is retained and released in 50% (L_{50}) to the length of mesh size "A" in the codend, measured wet,

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

- selection quality "Ws": value of ratio of length class of fish released and retained in 50% (L_{50}) to the length class of fish fully retained by the codend (L_{100}),

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

- selection effectiveness "N": percentage value of ratio of the number of fish which passed onto cover "n_o" to the sum of the same number of fish and the number of fish "n_w" in the codend and having a length not greater than those in the cover, i.e. length L_{100},

$$N = \frac{n_o \bullet 100}{n_o + n_w}$$

- relative selective length "l_{ow}": value of the ratio of mean fish length inside the cover "l_o" to the mean length "l_w" of fish inside the codend in percent; the value of this index gives some idea as to the size of fish escaping from the codend when compared with mean length of fish retained by the codend,

$$l_{ow} = \frac{l_o}{l_w} \bullet 100$$

- relative selective weight "m_{ow}": value of the ratio of mean weight of fish in the cover "m_o" to mean weight of fish inside the codend "m_w" expressed in percent; the value of this index illustrates the weight of fish escaping from the codend in comparison with the mean weight of fish retained by the codend,

$$m_{ow} = \frac{m_o}{m_w} \bullet 100$$

Measurements of total length of fish in the cover and the codend was made to the nearest centimetre below. Measurements of mesh size in the codend were carried out in the upper part of the codend at a distance of not more than 2 m from the codend ending and 2 meshes from lace hood meshes touching with codend-strengthening rope (Figure 1). The measurements were carried out immediately after the trawl retrieval (wet) with an international ICES caliper, at a preliminary tension of the mesh with a force of 4 kg. The size of mesh size was calculated as an arithmetic mean from 30 random mesh measurements. The frequency of measurements was the following: before trawl use, dry and wet, after the first haul (3 hours of use) and after each subsequent 15 hours of trawling.

Hauls used for the selectivity study of fishing gear should technically resemble typical commercial hauls. This was expressed in the fact that the study was conducted on a vessel with similar technical characteristics to those of typical fishing vessels used in that area, the use of a codend of similar construction to those used in commercial fishery, the use of a similar fishing gear and parameters of trawling like those used by commercial trawlers.

The selectivity study should be based on hauls fulfilling certain requirements, especially the following:

- general catch rate of a haul should not be smaller than about 300 kg of fish and not greater than several tonnes,
- the fish species analyzed should be present in the haul in a quantity of at least 3% of total haul weight,
- the fish species analyzed must be present in both the codend and the cover, in at least several length classes.

An attempt was made during the study to attain the average catch rate since only for such hauls it could be assumed that fish in the codend will have the opportunity of direct contact with the codend material and, as a result, will be able to escape from the codend, if its dimensions will allow.

4. EXPERIMENTAL PART

4.1 Fishing Effort and CPUE

The selectivity study was conducted on various Antarctic fishing grounds between October 1986 and mid-February 1987.

Fishing effort characteristics from experiments and CPUE for studied fish species are presented in Tables 1 and 2.

Thirty hauls were selected for the study, each of them lasting from 2 to 3 hours and being similar to commercial hauls of 3 hour duration. A relatively high catch rate, similar to those attained by commercial trawlers, was achieved around South Georgia. Quite high CPUE was also attained on the Elephant I. fishing ground in the third leg of the experiment. Catch rates in the other experiments were much lower - the catches on the Joinville fishing ground was so small that further tests were abandoned for methodological reasons. Differences in catch rates attained in different phases of experiments were most likely connected with fluctuations in biological parameters of bottom fish concentrations on those fishing grounds and did not depend to any degree on technical factors used in the experiments such as type of gear used, its rigging, trawling parameters, etc.

The material collected (Table 2) is most representative for bumphead notothenia, Scotia Sea icefish, and Antarctic icefish, and less representative for *Chaenodraco wilsoni* and *Chionodraco rastrospinosus*, while for South Georgia icefish it is least representative.

4.2 Changes in Mesh Sizes in the Codends

The data presented in Table 3 demonstrated that before trawl was in use, the actual mesh size in the codend with a nominal mesh size of 80 mm was (both dry and wet) larger by about 10% than the nominal size. After a trawl was in use this value increased to about 14% in comparison with the nominal value, reaching 90 mm. Such value remained at a stable level during the first phase of the experiment and for that reason it was assumed as the actual mesh size for that phase. During the tests, experimental work with this codend was suspended for some time. After resuming work it was discovered that mesh size decreased considerably and exceeded the nominal value by only 8.5%. This value remained at a constant level during further tests, so it was assumed as actual size for that stage of the study.

Changes in mesh size in codends with a nominal mesh size of 100 mm resemble those in the 80 mm codend (Table 3). During the study, due to a failure, one codend had to be replaced by another. Therefore there were two series of codend tests with the same nominal mesh size. Generally speaking, mesh size in both codends remained at a level larger by 10-11% than the nominal value. That is why a value of 110.6 mm was assumed as actual for the 100 mm codend.

4.3 Selective Properties of Codends

4.3.1 Bumphead notothenia

Selection of bumphead notothenia was evaluated several times during 6 experiments on four Antarctic fishing grounds. Three experiments were made with 80 mm codend and three with 100 mm mesh codend. Proper calculations were made for each of them and a selectivity ogive was drawn. Those data are presented in Figures 4 and 5 and in Table 4.

Analysis of selectivity curves for the 80 mm codend obtained on the basis of data collected on various fishing grounds (Figure 4) revealed a number of common features despite quantitative differences. The most important feature was that all of these curves had a different shape in comparison with a standard selectivity ogive for net materials with a high selectivity coefficient. They were characterized by a very clear shift towards retention of small fish at a relatively high level. The ascent of the curves was very slow, which corresponded with high values of selection intervals "Ps". Selectivity coefficients F_s were decidedly low, as well as selection quality coefficients. Selectivity effectiveness was decidedly small - with this mesh size a much greater number of fish could escape through the meshes. Mean length of fish released and at the same time retained by the meshes was relatively small, decidedly smaller than could be theoretically predicted. That is why a general evaluation of the selection of bumphead notothenia by the 80 mm codend could not be positive.

Analysis of the selectivity curves for the 100 mm codend with respect to bumphead notothenia revealed their similar features with 80 mm codend's ogive. The greatest similarity was that these curves were very flattened and their shape did not clearly indicate the length range, for which fish selection would be more distinct. It covered several length classes which was reflected in exceptionally high values of selection intervals P_s. Values of selectivity coefficients were also relatively small. Indices of relative selective lengths and weights of fish escaped and retained by the codend were exceptionally high, indicating that there were no significant size differences between fish retained and escaped from the codend. The length of fish with 50% retention (L_{50}) was higher than for 80 mm codend, however, it was still relatively small. Distinctly higher length values were obtained in the case of fish retained by 100% in larger codend.

Since selectivity ogives for the two codends revealed basically similar qualitative tendencies, it was decided to group together all results collected on various fishing grounds for each codend and calculate their combined selectivity coefficients (8). Combined ogives are presented in Figure 6, while values of selection of bumphead notothenia by two different codends are presented in Table 5.

A comparison of the shape of both curves indicated clearly that selection of both net materials was qualitatively similar although there were distinct quantitative differences. The selection of bumphead notothenia occurred definitely during trawling although both ogives were shifted to the area of small fish. Selection intervals for both ogives were very wide, and the values of selectivity coefficients were relatively low, especially in the case of 80 mm codend. Selection effectiveness increased from 20% for 80 mm codend to almost 50% in the case of larger meshes. Both length L_{50} and L_{100} increased also. A general conclusion from the comparative analysis is that although both nets select bumphead notothenia during trawling, this property is not high enough. The use of larger meshes distinctly improved selection properties of bumphead notothenia but not to such a degree that they might be considered sufficient from a practical point of view. Therefore, none from those codends could be positively evaluated. Most likely that closed meshes in the codend constituted such an obstacle for fish that an increase in mesh size did not really solve the problem, although it improved selection. It may be expected that keeping meshes open may solve the problem of selection of bumphead notothenia because this species has a distinct tendency of escapement from the codend during trawling.

4.3.2 Antarctic icefish

Studies of selectivity properties of Antarctic icefish by 80 mm codend were carried out on two fishing grounds: South Georgia and Elephant I., while for 100 mm codend - only on the Elephant I. fishing ground. Three ogives were obtained as a result of these studies (Figure 7) for each experiment. The obtained coefficients are listed in Table 6. An assessment of the Antarctic icefish selection was based on a relatively large number of initial materials. The ogives resembled much more the standard selectivity ogive than in the case of bumphead notothenia, although they were characterized by the same negative feature, i.e., they were shifted towards the area of length classes of small fish. This was evident from relatively low values of L_{50}, especially on the South Georgia fishing ground as well as relatively low values of selection effectiveness (35-64%). This meant that between 35 and 65% of fish in the codend with a length smaller than L_{100} did not escape. Coefficients L_{ow} and m_{ow} characterized the selection of Antarctic icefish very clearly. Especially the former index showed that there was no great difference between mean length of fish escaped from the codend and fish retained. Thus, a large part of fish could pass through the meshes but did not grasp this opportunity.

In order to compare selectivity properties of both codends for Antarctic icefish, selectivity ogives of 80 mm and 100 mm codends were drawn together in Figure 8. Table 7 presents main selection indices for those curves.

The shape of both ogives was very similar (Zaucha, 1987), a significant difference was in much greater shift of 80 mm selectivity ogive towards the area of small fish than in the case of 100 mm ogive. Selection of Antarctic icefish by two codends was clearly evident but practical results of this process was insufficient. This may be seen from relatively long, extended selection intervals and not too high values of selectivity coefficients of about 2.8. It should be emphasized that the use of 100 mm mesh size resulted in an almost twofold increase in selection effectiveness as well as an increase of L_{50} by 21%. A general conclusion is that standard mesh-size does not ensure selection of Antarctic icefish to a sufficient degree. It seems that the partly closed meshes during trawling constituted too big an obstacle for Antarctic icefish to be able to escape from the codend. It may be expected that permanently open meshes may ensure a proper level of selection of Antarctic icefish.

4.3.3 Scotia Sea icefish

Selection of Scotia Sea icefish by 80 mm codend was studied on three fishing grounds: South Georgia, Elephant I., and King George I., for 100 mm codend - two experiments were carried out on the Elephant I. ground. Because of very modest materials collected off King George I. and in the second phase of the experiment off Elephant I., data from the King George I. fishing ground were not taken for further detailed analysis and all data from Elephant I. for 100 mm codend were combined.

As a result of these experiments, two selectivity ogives were drawn for 80 mm mesh and one for 100 mm codend (Figure 9). A set of selection coefficients was calculated for each ogive (Table 8). The main drawback of the material collected was that relatively few fish passed through the net during those tests. Under these circumstances the most important segment of the ogive, concerning those fish classes which escaped from the codend was based on relatively scarce materials. A general feature of all selectivity ogives was their exceptionally large shift towards the area of small fish. As a result, the values of L_{50} were low (Table 8). A second feature of these ogives were very low values of index P_s, which gave a negative indication of selection of Scotia Sea icefish by the codend. Both too large and too small values of selection intervals point to abnormalities in the process of fish selection by the codend. Selection quality indices were very unsatisfactory. Equally negative were selection effectiveness coefficients. Very low, much lower than for fish analyzed before, were the values of index m_{ow}, which meant that fish escaping through the meshes had exceptionally small weight compared with the fish retained. Generally speaking, both the shape of the selectivity ogive and the selection indices indicated that the ability to select Scotia Sea icefish by both kind of codends was unsatisfactory.

In order to determine characteristics of Scotia Sea icefish selection by the two codends in a more precise, comparative way, two ogives were presented in Figure 10, one for each type of codend. Table 9 presents main selection coefficients for each of these codends (Zaucha, 1987).

The most important feature of both curves was their overlapping. This meant that the selection processes of both codends were similar. This conclusion is emphasized by data from Table 9. It appears from them that values of selectivity coefficients were very low, even lower for the net with larger meshes than with smaller meshes. Selection effectiveness was at a very low level. As a result a great number of fish which could escape because of their size, remained in the codend. The values of both L_{50} and L_{100} for both types of nets were the same, within the limits of an experimental error.

A general conclusion from these tests may be brought down to the observation that a change in the mesh size in the codend did not bring about a qualitative change in selection of Scotia Sea icefish. This gave rise to a fear that even the use of permanently open meshes will not bring the desired results, i.e., such as is expected in the case of Antarctic icefish and bumphead notothenia.

4.3.4 Chaenodraco wilsoni and Chionodraco rastrospinosus

Selectivity studies of these two species were based only on tests with 100 mm codend on the Joinville fishing ground. Selectivity ogives for the two species are presented in Figure 11, their selection parameters in Table 10.

Both the shape of the curves and the values of the parameters give an almost identical evaluation of the selection process of these fish by the standard codend. The values of selectivity coefficients and selection quality were low. Selection effectiveness was of particularly low value: 15% for *Chaenodraco wilsoni* and 10% for *Chionodraco rastrospinosus*. This meant that from 85 to 90% of fish did not choose to escape although their size allowed them for that. Parameters L_{ow} and m_{ow} were at a high level. This meant that as regards length and weight, there were no great differences between escaped and retained fish .

It is not surprising that a general appraisal of selectivity of the standard codend with respect to both species is decidedly negative, as in the case of Scotia Sea icefish. In this case it is also difficult to foresee whether permanently open meshes will improve the quality of selection of these fish to such a degree that it may be possible to evaluate it positively.

4.4 Additional Remarks

During the tests carried out on South Georgia fishing grounds, South Georgia icefish was found in the codend but no fish of this species were noted in the cover. Examination of length composition of fish in the codend revealed that although there were no juvenile South Georgia icefish, quite numerous were specimens with a length of 34, 35, 36 and 37 cm and larger. Fish with a length between 34 and 37 cm could, due to their sizes, pass through the meshes of the codend but did not use this opportunity. Under these circumstances a conclusion may be drawn that South Georgia icefish must find it extremely difficult to pass through the meshes of the codend during trawling so that even open meshes might not be an effective means of improving selection of this species.

5. CONCLUSIONS

1. Antarctic icefish and bumphead notothenia are subject to net selectivity of the commercial codend during trawling, but the effectiveness of this process in the case of standard nets, i.e. made of double polyamide twine, is insufficient. For that reason the use of codends believed to be good on other fishing grounds, cannot be practically recommended for commercial fishery on Antarctic fishing grounds irrespective of the established mesh size.

2. An increase in the effectiveness of selection of these fish species may be expected as a result of changing the construction of the codends, i.e. the use of permanently open meshes.

3. A tendency to escape from the codend during trawling of such fish as South Georgia icefish, Scotia Sea icefish, *Chaenodraco wilsoni* and *Chionodraco rastrospinosus* seems to be smaller than in the case of Antarctic icefish and bumphead notothenia. It is expected that the use of permanently open meshes in the codend would greatly improve the existing situation.

4. Ensuring proper selection of major Antarctic fish species by introducing one mesh size does not seem possible. The mesh size recommended at present

(80 mm) seems well chosen for Antarctic icefish, while for others like Scotia Sea icefish, South Georgia icefish and *Chionodraco rastrospinosus* it seems too small.

5. Experiments at sea should be urgently undertaken in order to confirm the observed tendency of arrested ability of Antarctic fish to pass out of a standard codend despite the fact that both mesh size and fish size theoretically ensure such a possibility. A suggested technical solution is a change of codend design so that meshes will not close during trawling. It is believed that such solution will effectively reduce fishing mortality of valuable species of Antarctic fish.

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Table 1: Characteristics of fishing effort in each of the experiments

Study period		27-29 Oct 1986	13-15 Nov 1986	15-16 Nov 1986	18-20 Dec 1986	13-4 Feb 1987	18 Feb 1987
Fishing ground		Elephant I.	Joinville I.	Elephant I.	South Georgia I.	Elephant I.	King George I.
Number of hauls		8	6	4	5	5	2
Trawling time (h)	total	20^{35}	18^{00}	10^{00}	14^{50}	10^{30}	3^{50}
	per haul	2^{34}	3^{00}	2^{30}	2^{58}	2^{06}	1^{55}
Catch (t)	total	5.89	1.52	1.49	14.39	10.43	2.89
	per 1 haul	0.74	0.25	0.37	2.88	2.09	1.44
	per 1 hour fished	0.29	0.084	0.15	0.97	0.99	0.75

Table 2: Catch rates of fish species subjected to the study in each of the experiments (in t/h and percent)

Study Period	27-29 Oct 1986		13-15 Nov 1986		15-16 Nov 1986		18-20 Dec 1986		13-14 Feb 1987		18 Feb 1987	
Fishing Ground	Elephant I.		Joinville I.		Elephant I.		South Georgia I.		Elephant I.		King George I.	
Fish species	tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%	tonnes	%
Bumphead notothenia	4.12	69.9	0.39	25.8	1.18	79.2	3.47	24.1	8.02	76.9	2.15	74.3
Antarctic icefish	0.15	2.5	-	-	0.04	2.5	8.12	56.4	0.78	7.4	-	-
Scotia Sea icefish	0.79	13.4	-	-	0.26	17.6	1.71	11.9	1.51	14.5	0.44	15.2
Chaenodraco wilsoni	-	-	0.90	59.5	-	-	-	-	-	-	-	-
Chionodraco rastrospinosus	-	-	0.08	5.2	-	-	-	-	-	-	-	-
South Georgia icefish	-	-	-	-	-	-	1.00	7.0	-	-	-	-
Other species	0.83	14.2	0.15	9.5	0.01	0.7	0.09	0.6	0.12	1.2	0.30	10.5
Total	5.89	100	1.52	100	1.49	100	14.39	100	10.43	100	2.89	100

Table 3: Changes in mesh size in the codends tested

Parameter	Nominal mesh sizes	No. of codend	Mesh size				
			Before use		During use		
			Dry	Wet	Wet		
					After 3 h	After 15 h	After 30 h
Mean mesh size (mm)	80	I	87.2	88.2	91.2	90.0	86.8
	100	I	106.1	107.4	109.4	110.0	-
		II	108.3	110.2	111.8	111.2	-
Standard deviation (mm)	80	I	2.88	2.46	2.69	2.83	2.40
	100	I	2.36	3.06	2.37	1.87	-
		II	2.67	2.56	2.54	2.20	-
Coefficient of change (%)	80	I	3.3	2.8	3.0	3.1	2.8
	100	I	2.2	2.9	2.2	1.7	-
		II	2.5	2.3	2.3	2.0	-

Table 4: Main selection parameters of bumphead notothenia

Selection parameter	80 mm codend			100 mm codend		
	South Georgia I.	Elephant I.	King George I.	Elephant I. (i phase)	Elephant I. (ii phase)	Joinville I.
No. of fish measured in codend	6 814	20 701	3 217	7 053	3 090	835
No. of fish measured in codend	2 198	2 826	420	8 526	1 328	761
P_s	12.0	7.2	6.2	10.2	13.6	14.0
F_s	2.02	2.28	2.88	2.84	2.10	2.64
W_s	0.48	0.52	0.64	0.74	0.59	0.72
N	36.3	14.7	28.1	55.3	30.7	48.3
L_{ow}	60.8	85.4	70.8	86.9	92.8	85.9
M_{ow}	15.6	48.6	28.9	74.2	75.7	56.5
L_{50}	18.2	19.8	25.0	31.2	23.6	29.4
L_{100}	38.0	38.0	36.0	42.0	40.0	41.0
L_{25}	14.1	17.8	22.2	25.4	18.2	20.0
L_{75}	26.1	25.0	28.4	35.6	31.8	34.0

Table 5: Main selectivity indices of bumphead notothenia for two codends

Index	P_s	F_s	N	L_{50}	L_{100}
80 mm codend	13.1	2.29	20.0	20.6	38.0
100 mm codend	16.8	2.63	49.8	28.9	42.0

Table 6: Main selection parameters of Antarctic icefish

Selection parameter	80 mm codend		100 mm codend
	South Georgia I.	Elephant I.	Elephant I. (i and ii phase)
No. of fish measured in codend	56 342	2 330	604
No. of fish measured in codend	29 851	1 841	1 035
P_s	6.8	5.4	8.0
F_s	2.56	3.22	2.82
W_s	0.66	0.73	0.78
N	34.8	45.9	64.1
L_{ow}	93.1	76.2	84.1
M_{ow}	78.4	32.3	48.5
L_{50}	23.0	28.0	31.1
L_{100}	35.0	38.0	40.0
L_{25}	19.8	24.8	26.0
L_{75}	26.6	30.2	34.0

Table 7: Main selection indices of Antarctic icefish for two codends

Index	P_s	F_s	N	L_{50}	L_{100}
80 mm codend	9.6	2.84	35.2	25.6	38.0
100 mm codend	8.0	2.82	64.1	31.1	40.0

Table 8: Main selection parameters of Scotia Sea icefish

Selection parameter	80 mm codend		100 mm codend
	South Georgia I.	Elephant I.	Elephant I. (i and ii phase)
No. of fish measured in codend	2 954	1 801	1 691
No. of fish measured in codend	133	44	125
P_s	2.5	3.9	5.4
F_s	2.29	2.48	2.09
W_s	0.59	0.72	0.59
N	7.5	25.6	25.7
L_{ow}	63.0	44.0	59.0
M_{ow}	13.3	2.7	8.4
L_{50}	20.6	21.5	23.0
L_{100}	35.0	30.0	39.0
L_{25}	20.0	20.1	20.6
L_{75}	22.5	24.0	26.0

Table 9: Main selection indices of Scotia Sea icefish for two codends tested

Index	P_s	F_s	N	L_{50}	L_{100}
80 mm codend	6.2	2.48	10.2	22.3	39.0
100 mm codend	5.4	2.09	25.7	23.0	39.0

Table 10: Main selection parameters of *Chaenodraco wilsoni* and *Chionodraco rastrospinosus* for 100 mm codend on Joinville fishing ground

Selection parameter	*Chaenodraco wilsoni*	*Chionodraco rastrospinosus*
No. of fish measured in codend	3 484	164
No. of fish measured in codend	651	11
P_s	10.1	1.9
F_s	2.12	2.66
W_s	0.63	0.75
N	15.8	9.2
L_{ow}	93.4	90.6
M_{ow}	88.3	69.6
L_{50}	23.4	29.4
L_{100}	37.0	39.0
L_{25}	19.9	28.4
L_{75}	30.0	30.3

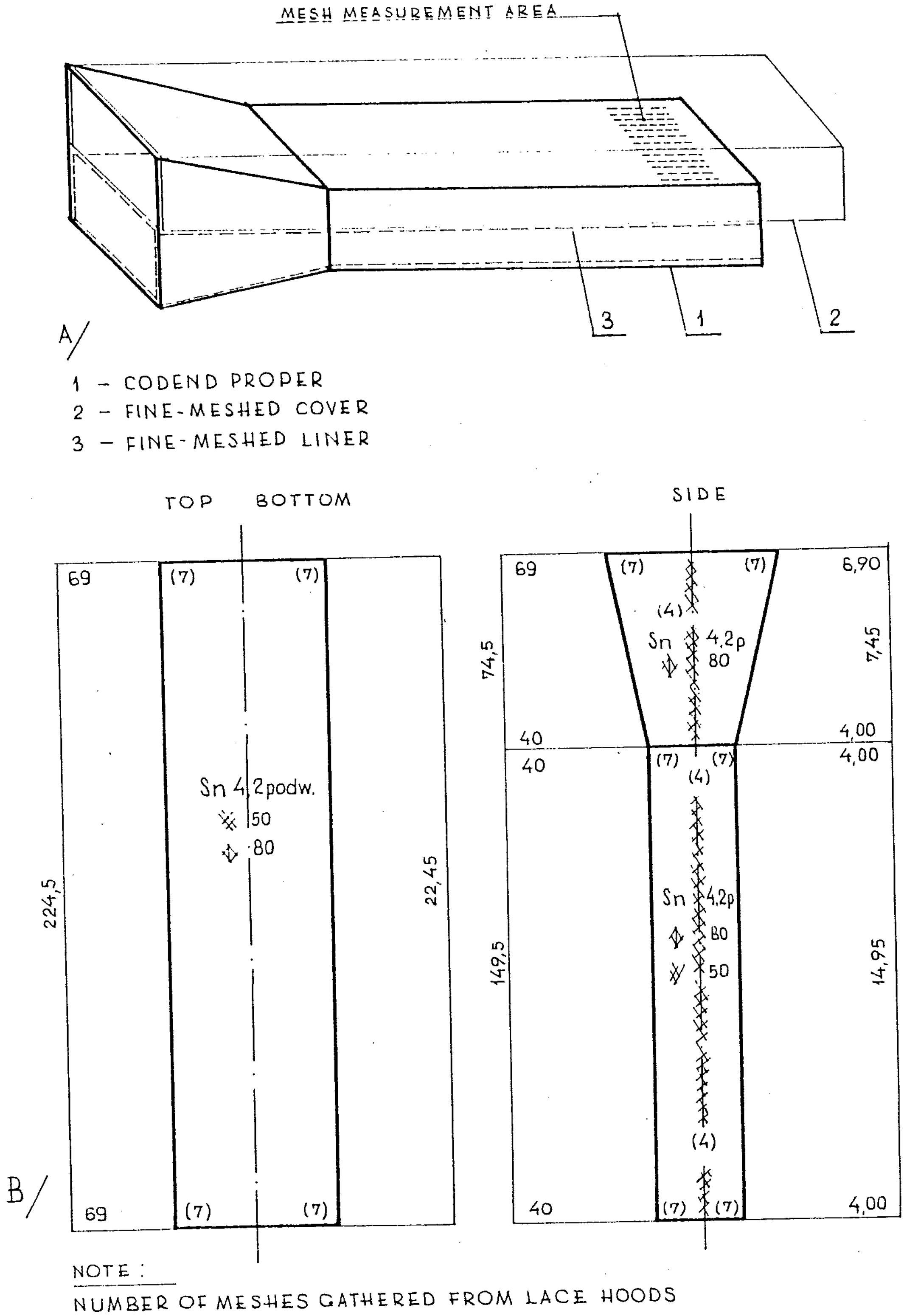

Figure 1: Schematic drawing of codend proper with cover and liner - for selectivity study (a) and construction of 80 mm codend proper (b).

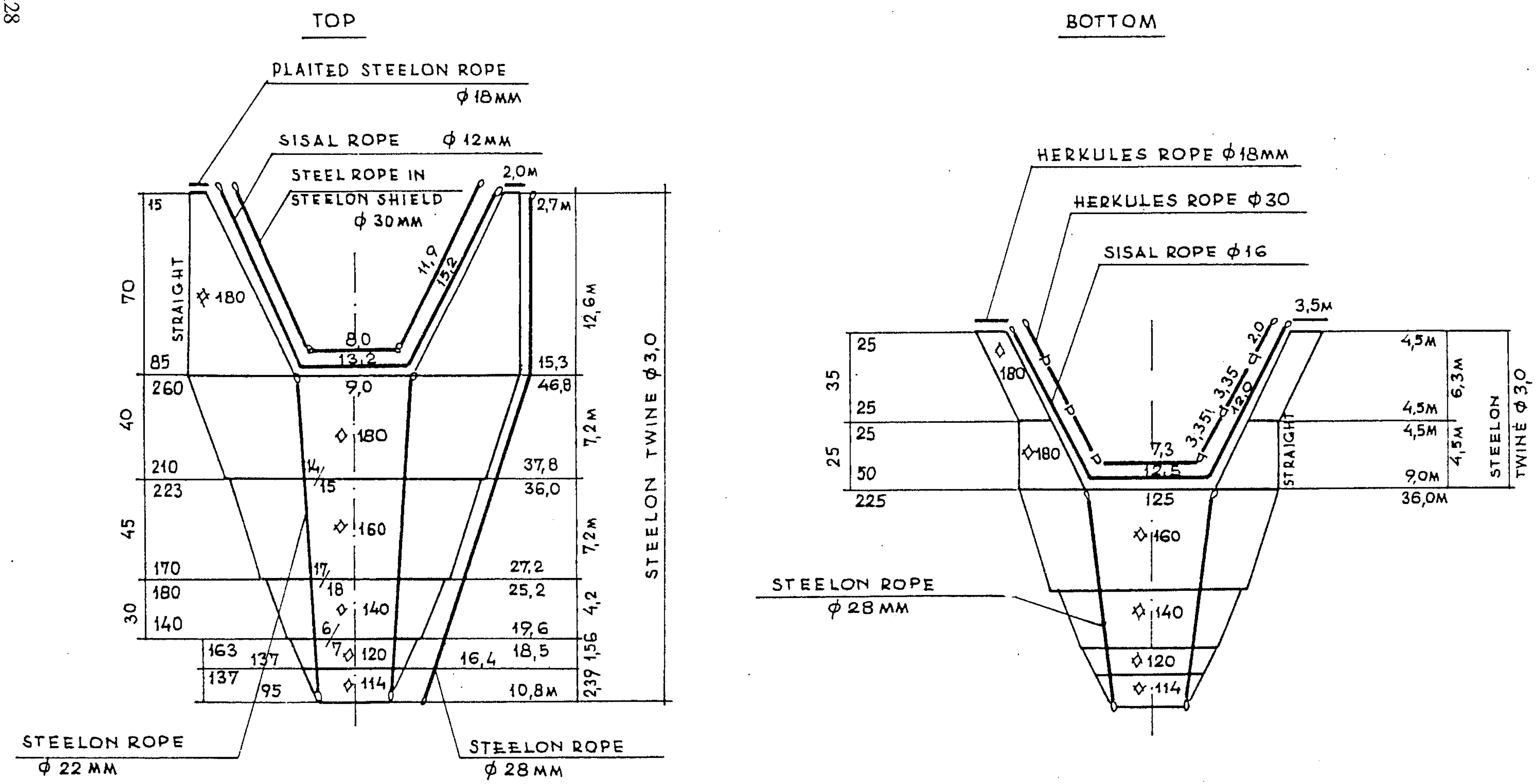

Figure 2: Schematic drawing of 32/31 bottom trawl construction

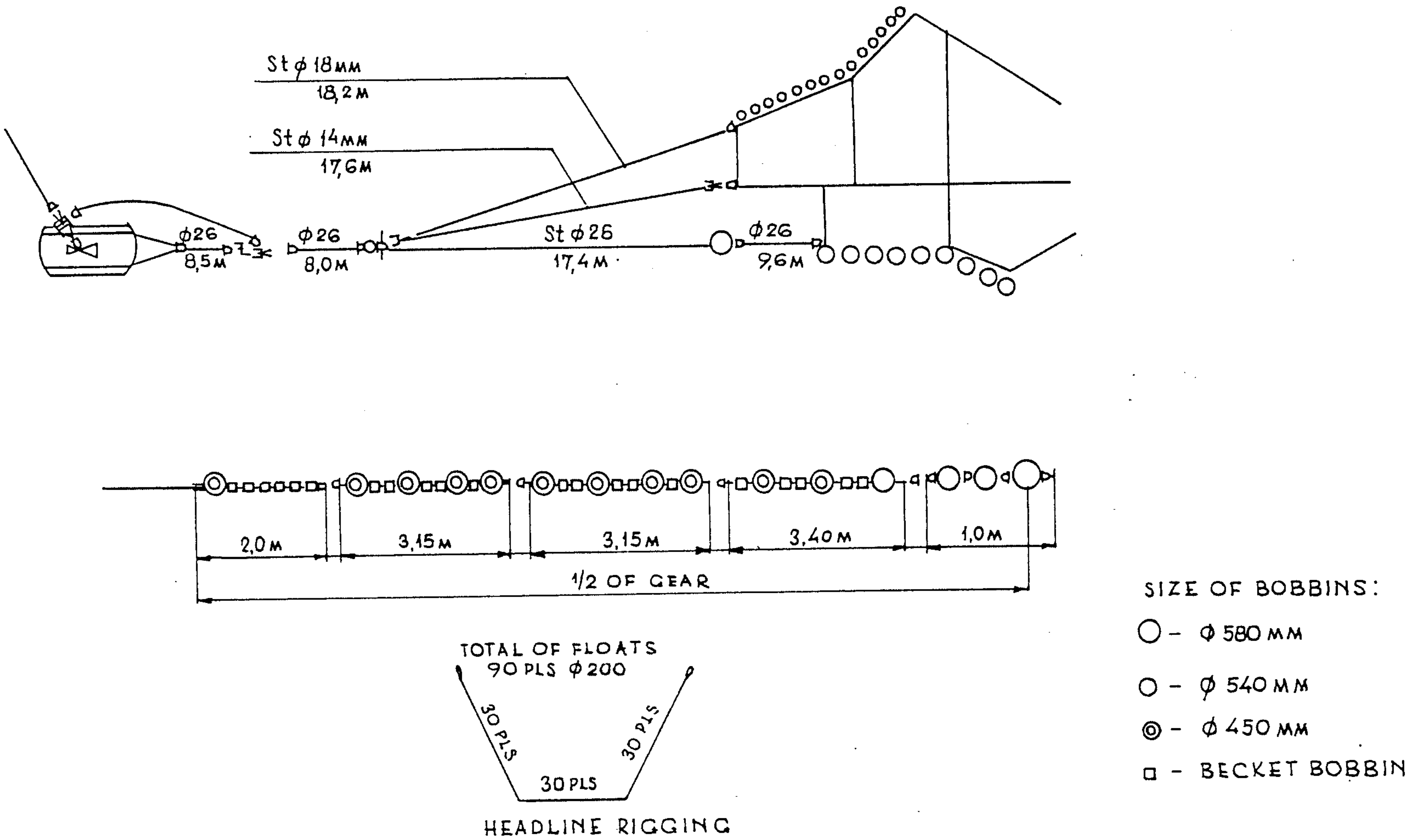

Figure 3: Schematic drawing of 32/31 bottom trawl rigging

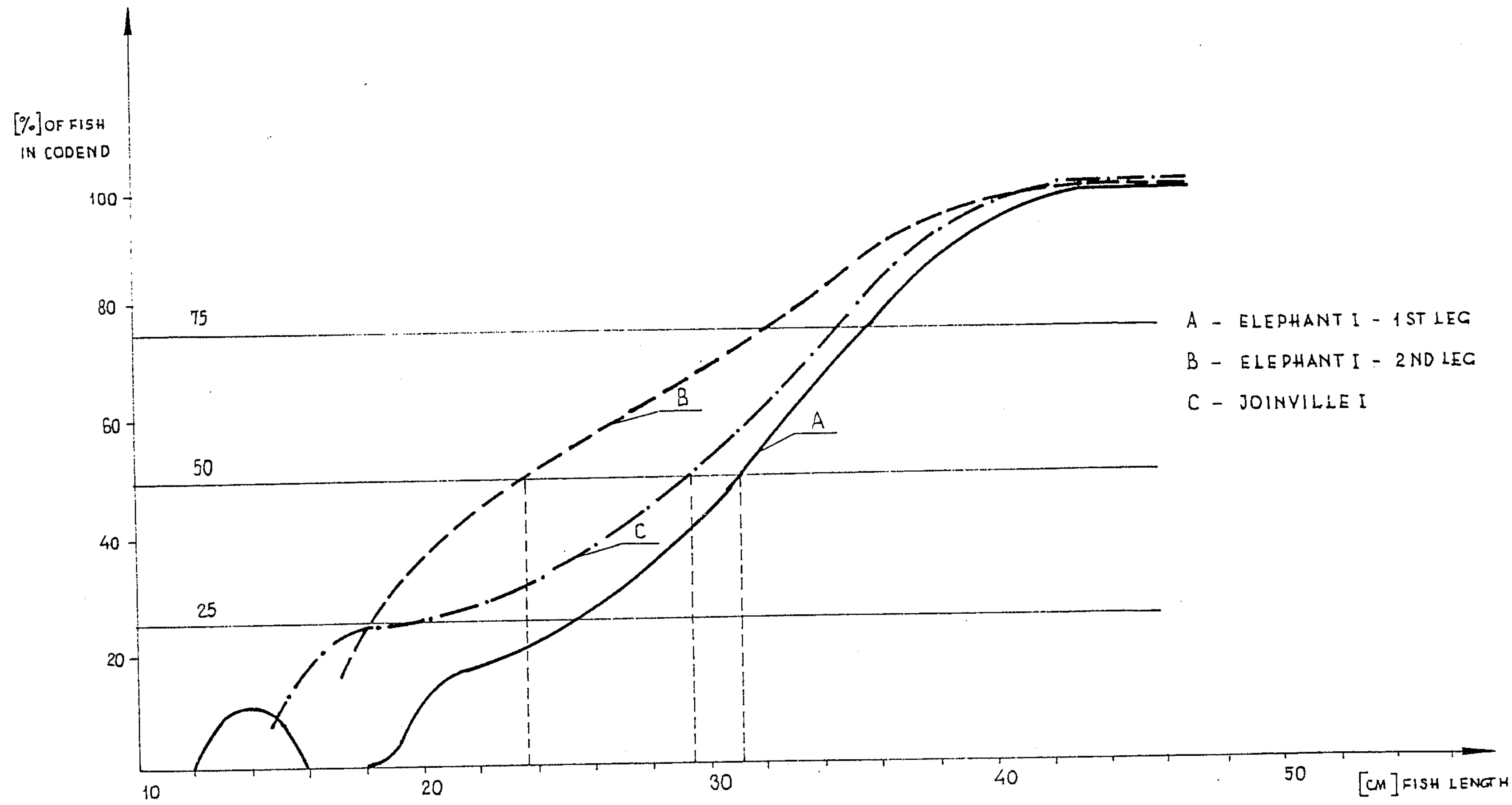

Figure 4: Selectivity ogive for bumphead notothenia by 80 mm codend

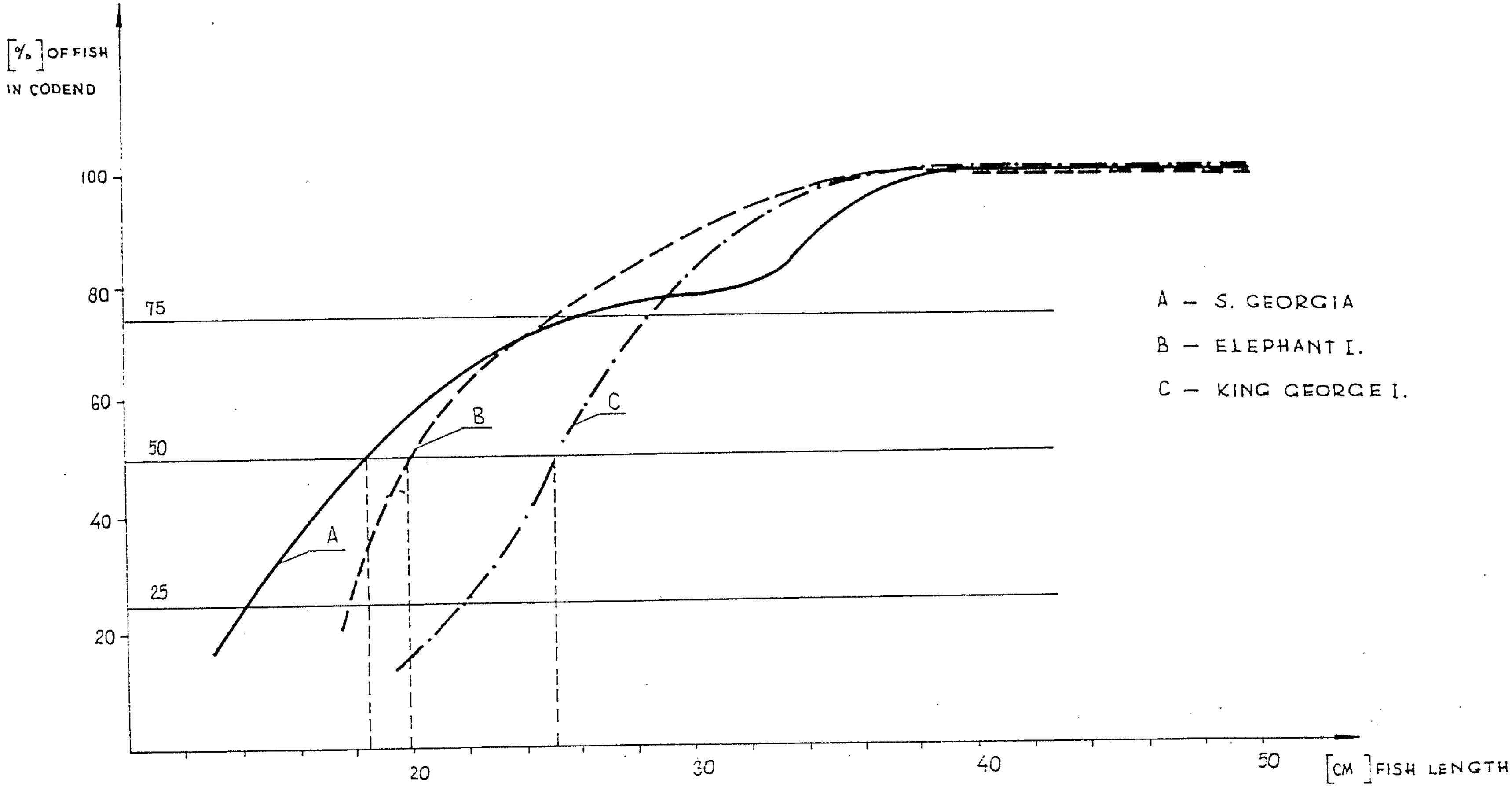

Figure 5: Selectivity ogive for bumphead notothenia for 100 mm codend

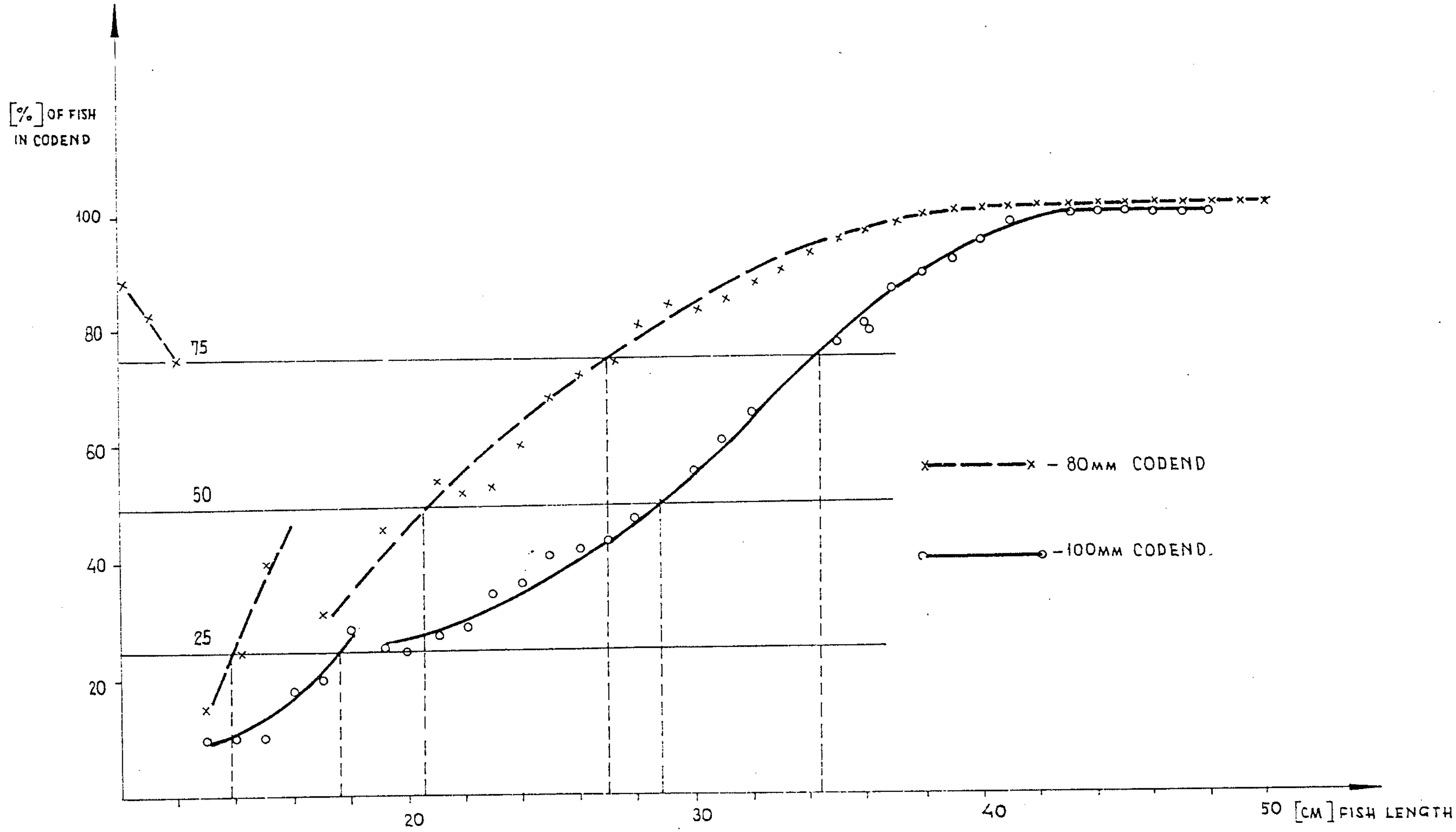

Figure 6: Selection of bumphead notothenia on Antarctic fishing grounds

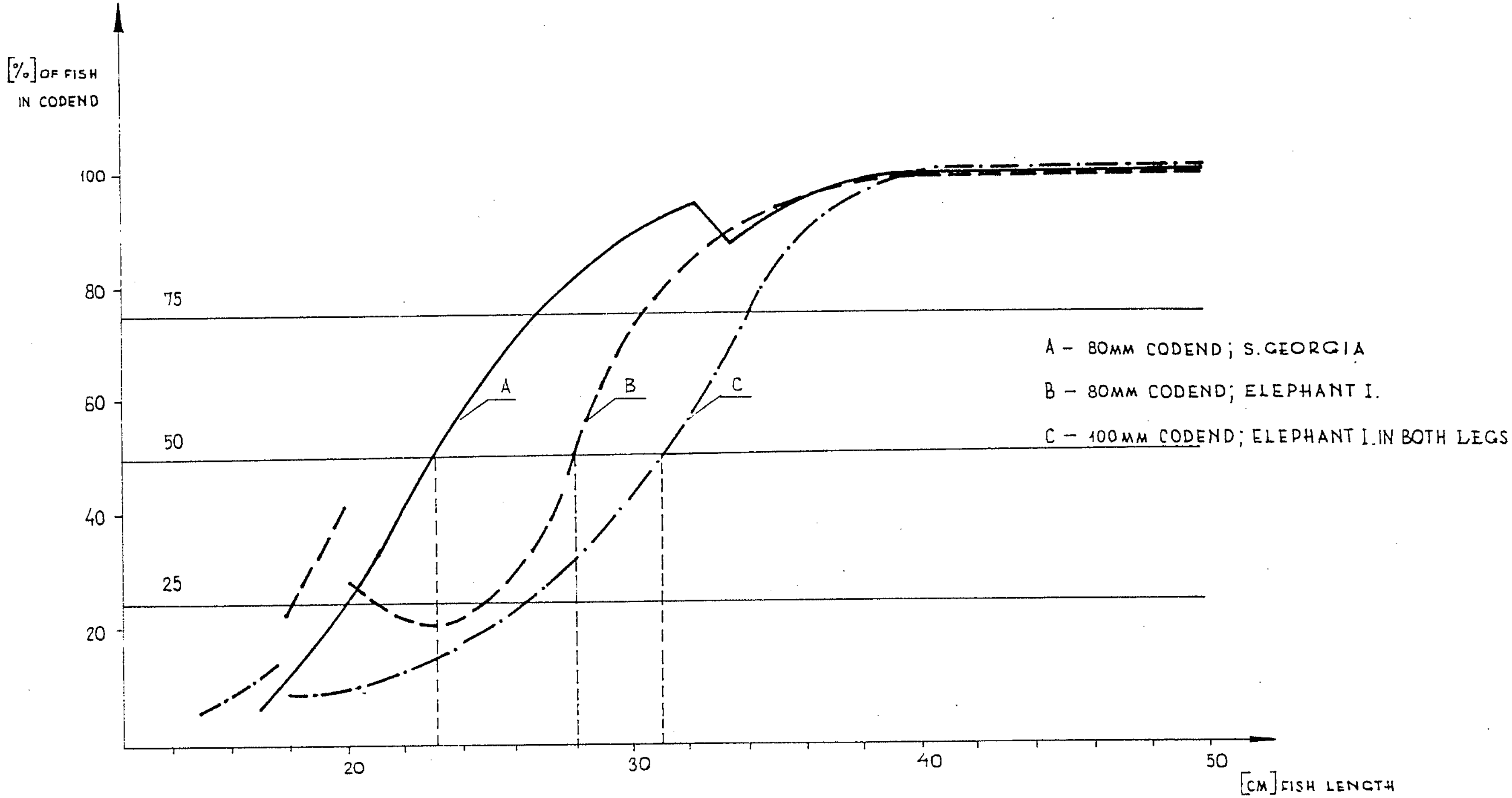

Figure 7: Selectivity ogive for Antarctic icefish by various codends on Antarctic fishing grounds

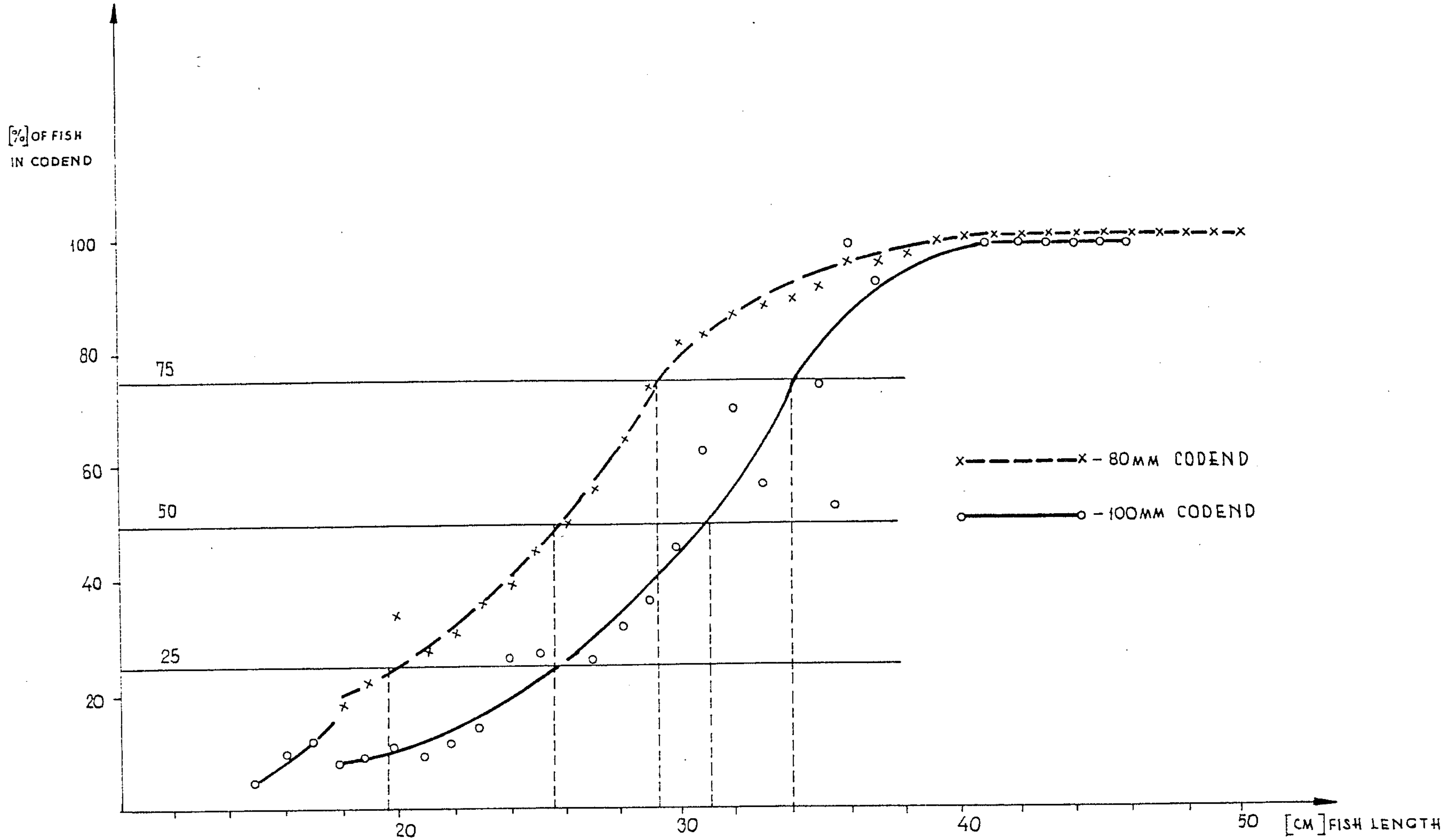

Figure 8: Selectivity ogives for Antarctic icefish on Antarctic fishing grounds

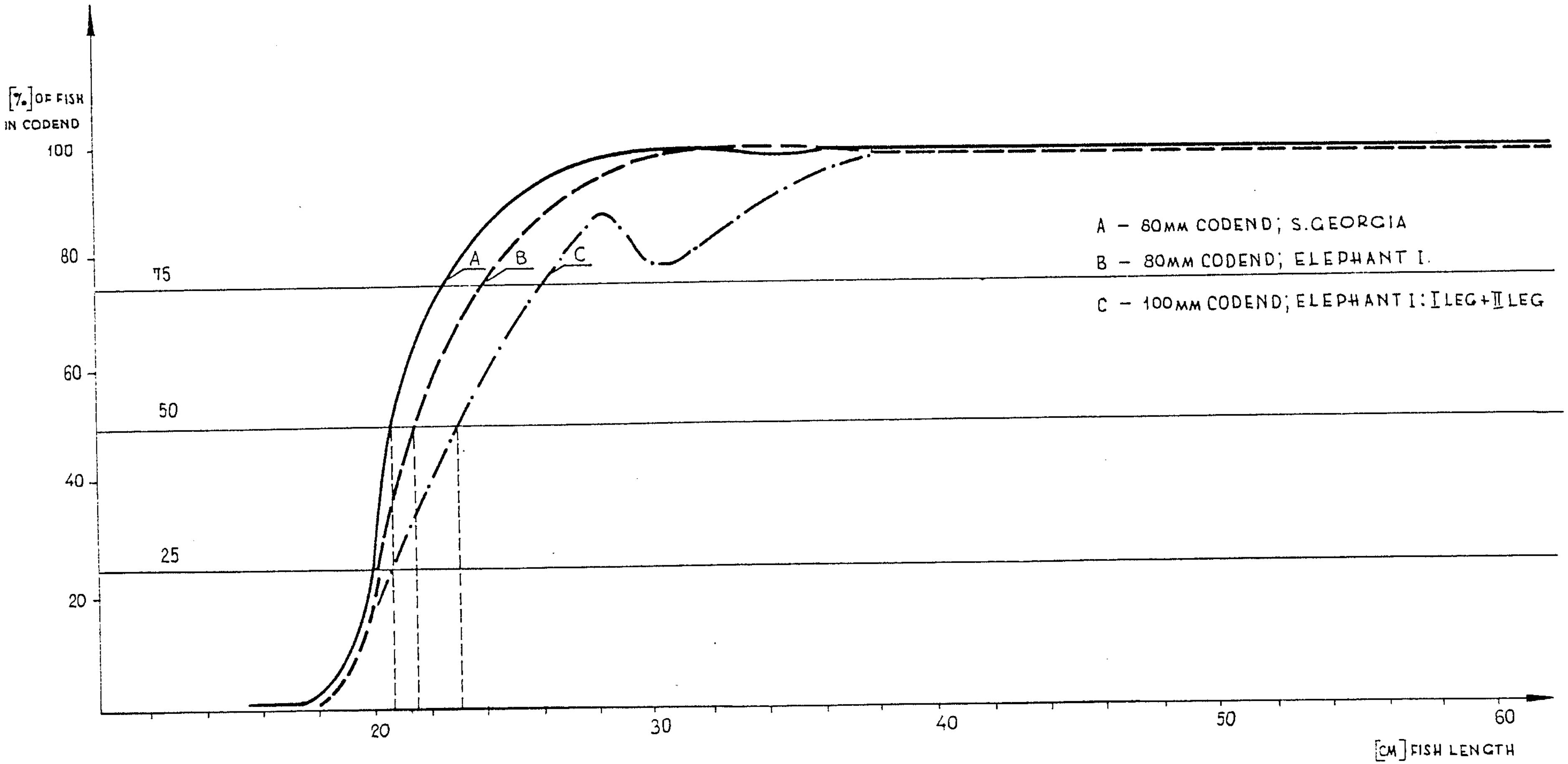

Figure 9: Selectivity ogive for Scotia Sea icefish on various fishing grounds by both types of codends

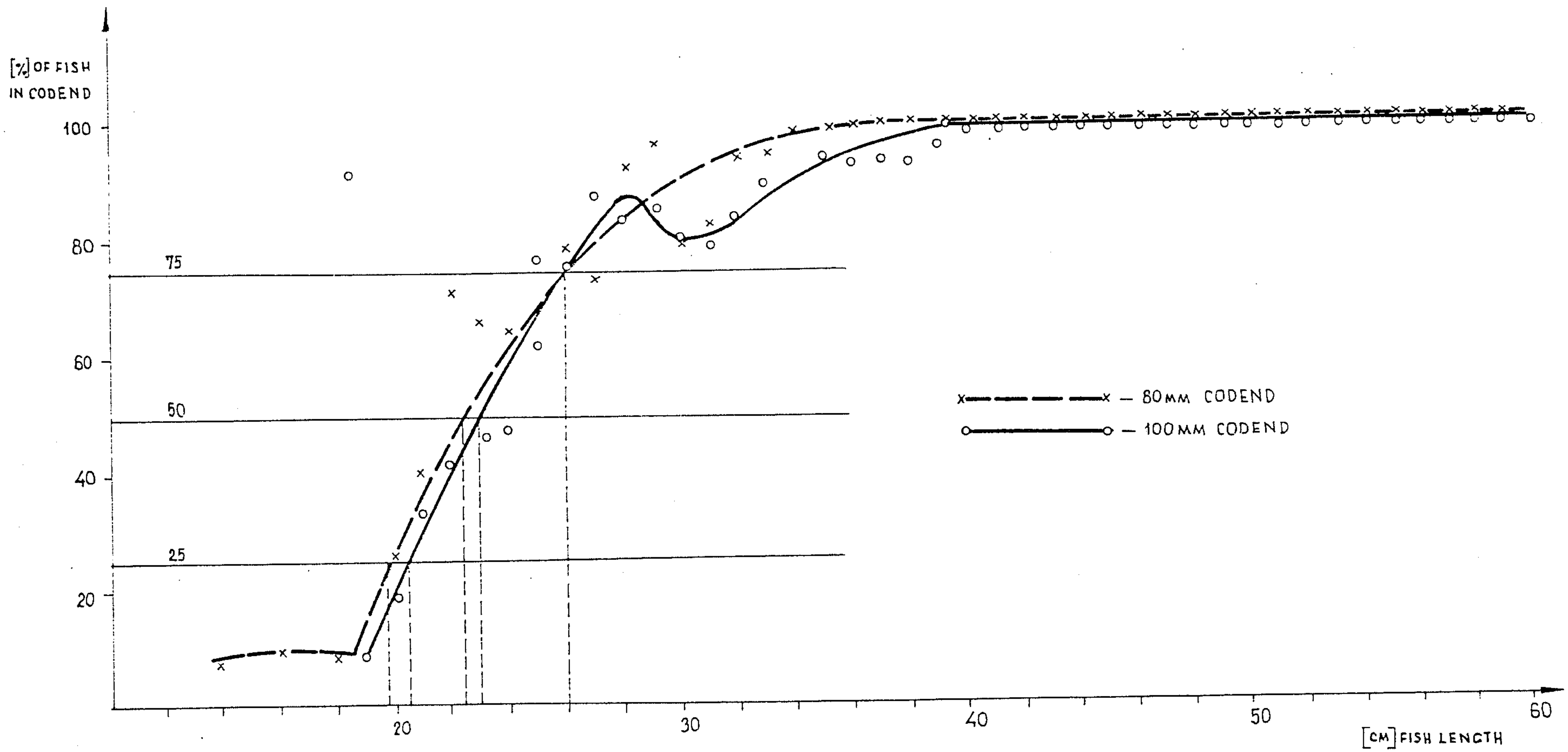

Figure 10: Selection of Scotia Sea icefish on Antarctic fishing grounds

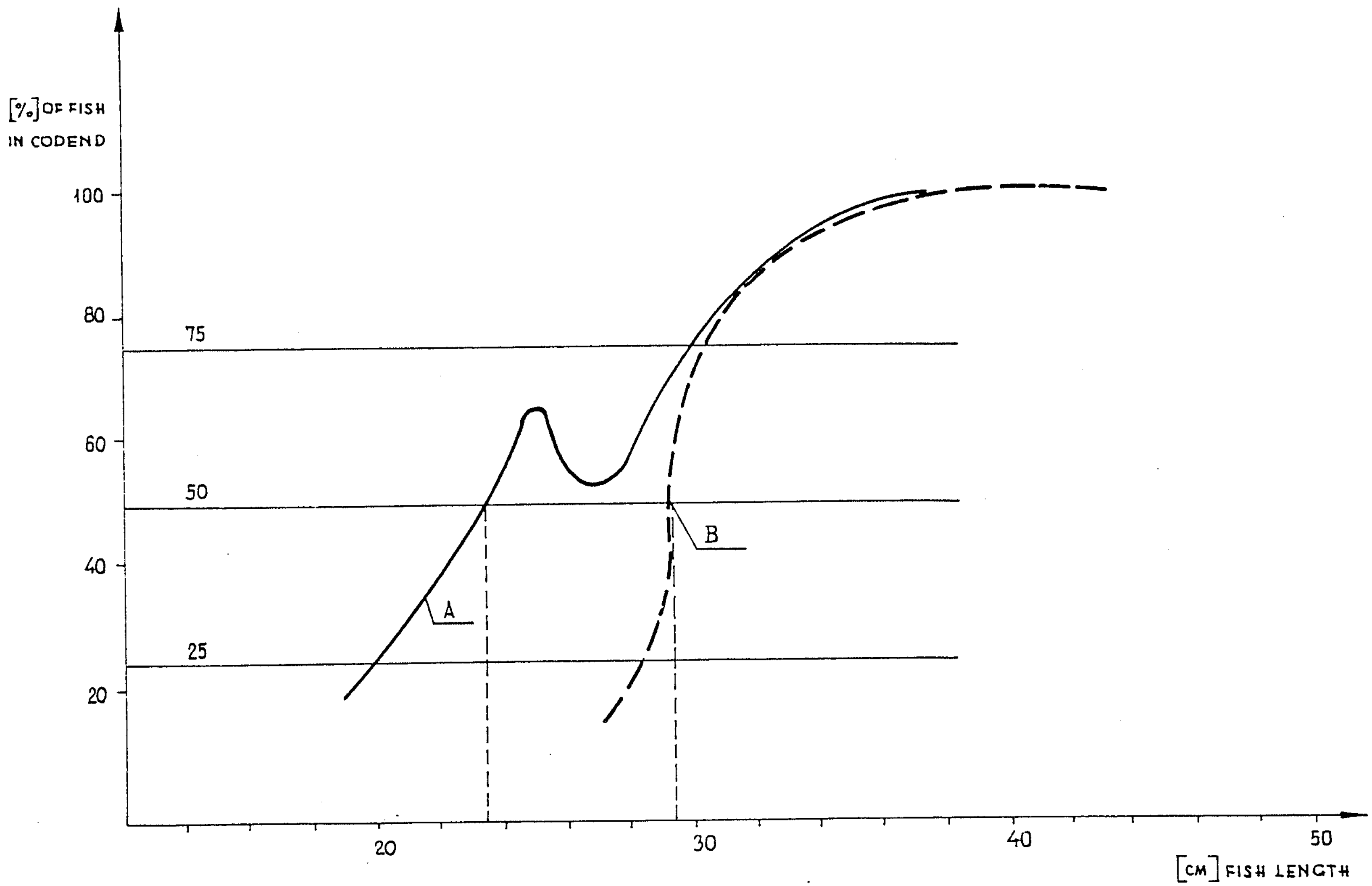

Figure 11: Selectivity ogives for *Chaenodraco wilsoni* (a) and *Chionodraco rastrospinosus* (b) on Joinville fishing grounds for 100 mm coded

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Рисунок 10 Селективность крокодиловой белокровки на промысловых участках Антарктики.

Рисунок 11 Огивы селективности кутка (размер ячеи 100 мм) для *Chaenodraco Wilsoni* (a) и *Chionodraco Rastrospinosus* (b) на промысловых участках у о. уэнвиль.

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