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SELECTIVITY EXPERIMENTS WITH DANISH SEINE ON COD AND HADDOCK IN NORTHERN NORWAY IN 1983

by

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ABSTRACT

In August-September 1983, selectivity experiments with Danish seine were carried out in northern Norway. Two commercial vessels were used and hauls with 110 mm and 135 mm mesh size were compared, using the alternate hauls method. A variance analysis was applied to the data, splitting the variance into a vessel, an area (station), and a selectivity component. The resulting selection factors were substantially higher for both cod and haddock than found in selectivity experiments in 1982, which were based on the covered cod-end method.

An alternative formula for the selection curve is introduced, based on the assumption that selection is chiefly a question of trial and error, and that body girth and head girth are relatively unimportant. The formula differs from those commonly used by having the mesh size as one of the parameters. The formula is discussed in the APPENDIX.

INTRODUCTION

In 1982, selectivity experiments with Danish seine on cod and haddock were carried out in northern Norway, using the covered cod-end method (Jakobsen 1983). In these experiments seine nets with 110 mm and 135 mm mesh were used. Selection factors of 3.6 for cod and 3.3 for haddock were found, and both values are lower than the corresponding selection factors of 3.96 and 3.63 found for trawl in the Barents Sea (Anon. 1979). The experiments were carried out partly because it had been decided that the minimum legal mesh size in Danish Seine north of 64^{0}N should be increased from 110 mm to 135 mm from 1 January 1983. Although the decision had been made before the experiments, the results became central in the argumentation for and against the mesh increase. The fishermen claimed that the mesh increase would reduce their catches substantially, especially of haddock, and the conclusions of the report from the selectivity experiments were challenged. The main argument from the fishermen was that the cover must have prevented the fish from escaping the net, and they demanded that comparative fishing with 110 mm and 135 mm mesh should be carried out. It was finally decided that the Institute of Marine Research should try to use this comparative fishing as a basis for selectivity experiments in August-September 1983.

MATERIAL AND METHODS

The experiments were carried out in the period 15 August - 24 September 1983 on the coast of northern Norway north of the Lofoten Islands. Most of the hauls were made in the North Cape area. Two commercial Danish seine vessels, "Cato Andre" (55 ft., 375 h.p.) and "Karl-Viktor" (60 ft., 370 h.p.) were used. The vessels were chosen because they were the two applicants most similar in size, engine power, and fishing equipment.

Two new nets with 110 mm and 135 mm mesh were bought for the experiments. The nets were of the type most commonly used in commercial fishing in northern Norway. Both nets had courlene in the wings and the foremost part of the funnel and nylon in the rest of the funnel and in the cod-end.

Danish seine fishing in northern Norway is carried out by first throwing over board a buoy to which one rope is fastened. The boat then moves in a circle while the rope, the net, and finally the other rope are set. Back in the position of the buoy, the net is hauled. During the hauling, the boat may be moving slowly forwards, although this is not in agreement with Norwegian regulations. The plan was that the two vessels should make parallel hauls. In practice this was not always possible, either because the fishing ground or concentration of fish was too small or because other fishing boats were in the way. In these cases, one boat had to wait until the other had finished.

During the experiment, in addition to some unsuccessful attempts, 30 "parallel" hauls were made. Details about the hauls are given in Table 1. The depth range was 15-90 fathoms, with 9 hauls at 15-35 fathoms, 20 hauls at 45-65 fathoms, and 1 haul at 80-90 fathoms. In addition to the "parallel" hauls, two hauls were made with "Karl-Viktor", using the 135 mm net and the same cover (60 mm meshes) which was used in the experiments in 1982.

The vessels changed nets twice during the experiments, giving "Karl-Viktor" the majority (18) of the hauls with 110 mm mesh (Table 1). Measurements of the mesh size were made six times during the cruise (Table 2). There was in most parts of the nets an increase of 1-2 mm during the early period of the cruise, but after that the mesh size appeared to be fairly stable. In ordering the nets, it had been stressed that the mesh size in the posterior part of the funnel should be the same as in the cod-end. Nevertheless, the measurements revealed considerable differences between the sections, especially for the 110 mm net. As average for the six series of measurements of the two nets the following mesh sizes were found: 111.0 mm and 136.9 mm (cod-end), 117.6 mm and 138.1 mm (posterior mid-section), 121.2 mm and 141.5 mm (anterior mid-section).

The total catch in the 30 "parallel" hauls was 20 399 cod, 3 669 haddock, 463 saithe, and insignificant quantities of other fish. All cod and haddock were measured. A record was kept of the fish which were found stuck in the meshes.

RESULTS

In addition to a large variation in the catches from station to station, there were also frequently large differences between the catches of the two nets in the "parallel" hauls (Table 1). In a few cases (St. 6, 11, 17, 19) this could be explained by one of the nets getting stuck, but mostly there was no apparent reason for the difference.

Tables 3 and 4 show the length distributions of cod and haddock respectively for each net at each station. In spite of the differences in numbers, the differences in length frequency distributions between 110 mm and 135 mm at most of the stations approach the differences that would be expected to result from selection. This is seen more clearly in Figs 1 and 2 which show for cod and haddock respectively the average length frequency distributions from "parallel" hauls where at least one of the nets had caught more than 100 individuals of the species (12 hauls for cod and 5 hauls for haddock).

Fig. 3 shows for each net the length distributions of all the cod which were found stuck in the meshes. Most of this fish was found in the posterior mid-section, from the transition to the cod-end and as much as 10 m ahead. The fish are clearly smaller than the average of those caught, but still cover a length range of more than 30 cm. The difference in size of the fish between the two nets is larger than for the total catches. Corresponding data for haddock were sparse and did not reveal a clear pattern.

CALCULATION OF SELECTION PARAMETERS

In the calculation of selection parameters, the formula

$$p = \left[1 - \left(\frac{m - 2al}{m}\right)^2\right]^b \qquad (1)$$

where p is the proportion retained of fish of length l by a net with mesh size m, and a and b are constants, has been used to describe the selection curves. A curve of this type could be fitted closely to observed selection curves from the experiment in 1982 (Jakobsen 1983). The formula differs from the more conventional ones by having the mesh size included as a parameter. A description of how the formula was deducted, some of its properties, and possible advantages, are given in the APPENDIX.

To the author's knowledge, the alternate hauls method has never been used in selectivity experiments with Danish seine. When alternate hauls have been used with trawls, one of them has usually been small-meshed to prevent selection. In such cases, the ratio of catch in the larger meshed trawl and catch in the small-meshed trawl for different length groups will theoretically describe the selection curve for the larger meshed trawl. For the more complicated case where selection takes place in both nets, a method for estimating the selection factor is described by Beverton and Holt (1957). The procedure involves the calculation of relative selection curves for the two nets, using a range of selection factors and assuming that the selection curve for each net is a normal ogive. The selection range is assumed to be the same for both nets. The final step is to compare the theoretical curves with the observed values to see which selection factor gives the best fit. This procedure is in principle not restricted to normal distribution selection curves. Using formula (1), the ratio of catch in number at length l for two nets A and B where B has the larger mesh, is given by

$$\frac{\text{Catch B}}{\text{Catch A}} = \left[\frac{m_A^2}{m_B^2} \; \frac{m_B - al}{m_A - al} \right]^b \qquad (2)$$

Fig. 4 shows an arbitrary example of selection curves for 135 mm and 110 mm mesh, and the resulting relative selection curve for the two nets, using the formulas (1) and (2). Figs 5 and 6 demonstrate how the relative selection curve changes with selection factor and selection range respectively.

With the alternate hauls method, some scaling of the catches is often necessary. This is usually done by assuming that the catches of fish large enough to be unaffected by selection in the larger meshed trawl, should have been the same for both trawls. With the current data set, the main problem is that the scaling requires an estimate of the upper limit of the range of selection for the 135 mm net. Figs 7 and 8 show how the observed relative selection curves for cod and haddock respectively, change depending on the assumption of this limit. Comparison with the curves on Figs 5 and 6 demonstrates that the choice of upper length for selection is crucial for the estimates of both selection factor and selection range.

An alternative approach is to use a statistical analysis. A variance analysis in the GLIM package (Baker and Nelder, 1978) was applied to the data sets. This analysis splits the variance into an area (station), a vessel, and a mesh size component and the latter should in theory describe the relative selection curve, giving also the 95% confidence limits of the estimates for each length group. The 4 stations (6, 11, 17, 19) where one of the nets was clearly stuck during the hauling, were excluded from the analysis. The curves resulting from the analysis are shown on Figs 9 and 10 for cod and haddock respectively. The curve for cod differs from the curves presented on Fig. 7 by staying at a higher level over the lower range of length groups. For haddock the correspondence with the curves on Fig. 8 appears to be good. The analysis also revealed what was already suspected from the catches, that "Cato Andre" had been much more efficient than "Karl-Viktor".

The final step step in the estimation of the selection parameters, is to find the values of a and b that give the best fit to the curves in Figs 9 and 10. The selection factor is then given by the formula

$$\text{S.F.} = \frac{1 - \sqrt{1 - 0.5^{\frac{1}{b}}}}{2a} \qquad (3)$$

and the selection range $l_{75} - l_{25}$ by the formula

$$l_{75} - l_{25} = \frac{m}{2a} \left(\sqrt{1 - 0.25^{\frac{1}{b}}} - \sqrt{1 - 0.75^{\frac{1}{b}}} \right) \qquad (4)$$

In fitting formula (2) to the curves in Figs 9 and 10 a least square fit by 5 cm length groups was applied. For cod it was not possible to get a satisfactory fit when all length groups were included, chiefly because of the high level of the left-hand side of the curve. The fitting procedure for cod was therefore restricted to the length interval 50-70 cm which is likely to be most reliable in estimating the selection factor. The fitted curves are included on Figs 9 and 10. Because of the observed differences between the meshes in the cod-end and those in the mid-section (Table 2) it was not clear which mesh sizes were most representative for the nets. Trials showed that the range of choices was too small to be of great significance for the selection factor, but there would be some effect on the estimate of selection range. Only the cod-end meshes of 111.0 mm and 136.9 mm are used in the calculations presented here.

The values found for a and b were, cod: a = 0.091, b = 14.5; haddock: a = 0.096, b = 15.5. The estimated selection factor was 4.3 for cod and 4.1 for haddock. The selection range is assumed to be proportional to the mesh size. The values for 136.9 mm and 111.0 cm were 12.2 cm and 9.9 cm respectively for cod and the corresponding values for haddock were 11.2 cm and 9.1 cm.

DISCUSSION

The selection factors of 4.3 and 4.1 estimated for cod and haddock are substantially higher than the corresponding values of 3.6 and 3.3 found in the covered cod-end experiments in 1982 (Jakobsen 1983). They are also higher than the selection factors 3.96 for cod and 3.63 for haddock found for otter trawl in the Barents Sea (Anon. 1979). The difference between cod and haddock is relatively consistent.

The difference between the results from 1982 and 1983 may reflect systematical errors in either the covered cod-end method or the alternate hauls method, or possibly both. The errors may be inherent in the methodology or may be related to the way the experiments were conducted in practice. One possible source of error that was pointed out by the fishermen is masking. During the 1982 experiments, it was felt that the cover was working as intended and that there should be plenty of room for the fish to escape. In retrospect, the suspicion arises that in the relatively shallow waters where the experiments were conducted, the cover may have been too clearly visible and thus has frightened the fish. Another possibility is that the strong tidal currents often experienced on the Danish seine grounds have made the cover stick to one side of the net. During the 1983 cruise, one successful haul was made with "Karl-Viktor" using the 135 mm net and the same cover as in the 1982 experiments. The result indicated a selection factor for cod of about 3.85, which is 0.25 higher than the average from 1982, but within the range of values from single hauls. This haul confirms that the two methods give different results, but indicate that part of the observed differences between 1982 and 1983 may be due to differences in selectivity related to the vessels. Surprisingly, the vessel used in 1982 gave the lower selection factors, in spite of being smaller (51 ft.) and having less engine power (275 h.p.) than those used in 1983.

The covered cod-end method is relatively simple to handle mathematically. For cod some haul to haul variation was found in 1982, but the selection factor could apparently still be estimated with reasonable accuracy. For haddock the data were less convincing, but a difference from cod was indicated which corresponded well with that found in trawl.

The validity of the results from the alternate hauls method may be questioned both from a practical and a theoretical point of view.

The main practical problem is for two vessels to make hauls that are directly comparable. In northern Norway, this is clearly much more difficult for Danish seine than for trawl. To get reasonable catches, the fishermen have to use their sonars and in commercial fishing a high degree of skill is involved. The fishing often takes place on small grounds and the tidal currents play a major part in the success of the fishing. Judging by the size of the catches, few of the "parallel" hauls in 1983 were directly comparable. However, this can partly be ascribed to the difference in efficiency between the vessels, and the length frequency distributions from the two nets in most cases appeared to be in reasonable agreemeent with what could be expected taking into account the differences in mesh size. However, in some cases other factors than selectivity had obviously been at work. The problem is to decide on a non-subjective basis which hauls shall be included in the final analysis. In this case, some hauls with odd-looking results were included and this may have created some errors. However, trials (e.g., excluding hauls with zero catch) indicated that the effect of including the evidently non-comparable hauls was small. The results of the variance analysis were also in good accordance with what was suggested by a preliminary examination of each pair of "parallel" hauls.

Normally, the choice of formula for the selection curve will not be very crucial for the estimate of the selection factor. However, in this case the use of two nets with overlapping selection ranges means that a wider range of the selection curve is involved in the estimate of the selection factor. Still, the difference in mesh size is relatively large and in the 110 mm net there will be little selection of fish of length equal to l_{50} for 135 mm, unless a very wide selection range is assumed. This means that the ratio corresponding to l_{50} for 135 mm on the relative selection curve is unlikely to be much influenced by the choice of formula for the selection curve (Fig. 4). Since the formula (1) used here gave a very good fit to observed values from the 1982 experiment, there seemed to be no reason to assume that it would be preferable to use other selection curves.

For cod it was not possible to make the theoretical curve fit the values for the smallest length groups. The reason for this is not clear, but it may be partly related to the fact that the observed values are based on a series of hauls, which normally would mean that the resulting selection range is larger than for single hauls. A formula representing selection curves of single hauls may therefore not necessarily fit well. Especially the shape of the curve around l_{50} may be biased if all length groups are included in the fitting procedure. However, the level over the smaller length groups is considerably higher for the curve estimated by the variance analysis (Fig. 9) than the direct observations (Fig. 7) show. This indicates that the high level of the estimated curve may not be real, and the variance analysis not totally reliable.

The lack of experience with this type of selectivity experiments makes it difficult to evaluate the results. An argument for accepting the results may be found in the measurements of the cod stuck in the net (Fig. 3). The largest individual found in the 135 mm net was 72 cm and this may correspond closely to the upper limit of selection. From Figs. 5 and 7 it can be seen that this will give a value of l_{50} close to the 59 cm estimated from the variance analysis.

REFERENCES

Anon. 1979. Report of the Arctic Fisheries Working Group. Coun. Meet. int. Coun. Explor. Sea, 1979 (G:20): 1-85.

Baker, R.J. and Nelder, J.A. 1978. The GLIM system. Release 3. Generalised linear interactive modelling. (Manual). Numerical Algorithms Group, NAG Central Office, Oxford.

Beverton, R.J.H. and Holt, S.J. 1957. On the dynamics of exploited fish populations. Fish. Invest., Lond. (2), 19: 1-533.

Jakobsen, T. 1983. Selectivity experiments with Danish seine on cod and haddock in northern Norway in 1982. Coun. Meet. int. Coun. Explor. Sea, 1983 (B 18): 1-25.

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APPENDIX

The development of the selection curve formula.

Observation of the fish stuck in the meshes showed that nearly all had got the head through and were unlikely to be able to struggle back into the net because the netting would then tend to be caught under the gill-covers. The ratio between the number of fish stuck and the estimated number escaped increased with the length of the fish (Fig. 3), but was generally low (about 10 per cent at l_{50}). Apparently, if the fish got its head through the meshes, it would mostly manage to get the rest of the body through. This indicates that the body girth was of relatively little importance. Unless one assumes that the shape of the selection curve is caused chiefly by some size-related escape behaviour, most of the fish retained by the net must have made attempts to get through. The conclusion of all this is that the fish frequently give up their escape attempts at some stage before they get the netting past the gill-covers, and because the selection curve tends to have a sigmoid shape, the frequency of failed attempts must be a function of fish length and mesh size.

For the largest individuals, the head girth may prevent the fish from getting their heads through the meshes, but this can hardly be the reason why smaller fish fail to escape. It seems that the fish backs away from the net if it meets a certain degree of resistance.

The line of arguments in the preceeding paragraphs lead to an attempt to describe the selection mathematically, starting out with the following assumptions: Each fish has on its snout a sensitive area which is circular seen from the front and has a diameter proportional to the length of the fish. When trying to escape, the fish swim perpendicular to the net. The fish cannot see the netting and hit the meshes randomly. The meshes are open and square. If the fish hits the netting with the sensitive area of the snout it will turn away, if not it will escape through the mesh. The frequency of escape attempts is the same for all the fish.

Simple geometrical considerations involving a square (the mesh) and a circle (the sensitive area) logically lead to the following formula for the proportion p of fish of length l retained in the net:

$$p = \left[1 - \left(\frac{m - 2al}{m} \right)^2 \right]^b$$

In this equation, m is the mesh size, l is the length of the fish (the same unit of length must be used for m and l), a is the ratio between the diameter of the sensitive area and the length of the fish (i.e., al is the diameter), and b is the maximum number of escape attempts. The value of a is likely to be fairly constant for a species. The value of b may be dependent on the species and possibly on the duration of the haul. Since the mesh size is included in the formula, it follows that the selection range will be proportional to the mesh size if the values of a and b are unchanged. The curve is assymmetrical and the range $l_{50}-l_{75}$ is smaller than the range $l_{25}-l_{50}$ for values of b larger than about 2.71. The upper limit of selection is defined by $l = m/a$. The selection factor is given by the formula

$$S.F. = \frac{1 - \sqrt{1 - 0.5^{\frac{1}{b}}}}{2a}$$

and is independent of mesh size. It is increasing if a is decreasing and b is increasing. The selection range $(l_{25}-l_{75})$ is given by the formula

$$l_{75} - l_{25} = \frac{m}{2a} \left(\sqrt{1 - 0.25^{\frac{1}{b}}} - \sqrt{1 - 0.75^{\frac{1}{b}}} \right)$$

Knowing the mesh size, the parameters of selection are thus given if the values a and b can be found.

The curve could be nicely fitted to the observed data from the 1982 experiments. However, a sophisticated program for the fitting procedure has not been worked out. In this case, a least square fit by 5 cm groups was used, but this was time-consuming and involved a good deal of trial and error when carried out on an HP 67.

The assumptions made before arriving at the formula are at best over-simplifications of what actually happens in the net during a haul, and there are a lot of obvious arguments against them: The meshes are likely to be diamond-shaped rather than square, the sensitive area, if it exists, is likely to be anything but circular, the opportunity to escape is hardly the same for all the fish, etc. If the general idea is correct, such things could possibly be incorporated in the formula, but this would probably be a much more complex equation including additional parameters which would complicate the fitting of the curve to observed data.

It is also possible there are faults in the argumentation about the nature of selection, and it may even be disproved by factual evidence, in which case the formula will be only another unfounded mathematical description of the selection curve. However, even as such, it has the merit of fitting observed data satisfactorily and in some types of work, e.g., in calculations of the effects of changing the mesh size in a fishery, the formula would seem to have advantages because it requires only the value of m to be changed.

Table 1. Stations with "parallel" hauls during selectivity experiments with Danish seine in August-September 1983.

Station no.	Date	Position	Vessel	Mesh size (mm)	Depth (fath.)	Catch (numbers) Cod	Haddock
1	19.8	N71°06' E26°03'	"Cato Andre"	110	31	166	3
"	"	" "	"Karl-Viktor"	135	30	153	15
2	19.8	N71°05' E26°03'	"Cato Andre"	110	45	448	563
"	"	" "	"Karl-Viktor"	135	50	65	153
3	20.8	N71°05' E26°03'	"Cato Andre"	110	45	253	59
"	"	" "	"Karl-Viktor"	135	45	25	125
4	22.8	N71°05' E26°03'	"Cato Andre"	110	25	2905	64
"	"	" "	"Karl-Viktor"	135	25	735	28
5	25.8	N71°05' E26°03'	"Cato Andre"	110	45	1344	151
"	"	" "	"Karl-Viktor"	135	50	290	96
6	26.8	N71°05' E26°03'	"Cato Andre"	110	25	-	-
"	"	" "	"Karl-Viktor"	135	32	148	36
7	26.8	N71°05' E26°03'	"Karl-Viktor"	110	45	670	100
"	"	" "	"Cato Andre"	135	55	1024	142
8	29.8	N70°53' E29 25'	"Karl-Viktor"	110	50	16	9
"	"	" "	"Cato Andre"	135	52	18	14
9	29.8	N70°52' E29°45'	"Karl-Viktor"	110	27	4	4
"	"	" "	"Cato Andre"	135	40	58	3
10	1.9	N70°46' E29°58'	"Karl-Viktor"	110	80	43	31
"	"	" "	"Cato Andre"	135	90	1010	41
11	2.9	N70°46' E29°40'	"Karl-Viktor"	110	55	5	18
"	"	" "	"Cato Andre"	135	58	4	-
12	3.9	N70°58' E28°58'	"Karl-Viktor"	110	49	96	2
"	"	" "	"Cato Andre"	135	44	94	2
13	3.9	N70°58' E29°02'	"Karl-Viktor"	110	45	159	44
"	"	" "	"Cato Andre"	135	45	-	-
14	3.9	N70°53' E29°47'	"Karl-Viktor"	110	34	70	-
"	"	" "	"Cato Andre"	135	35	2	-
15	5.9	N70°53' E28°48'	"Karl-Viktor"	110	16	266	-
"	"	" "	"Cato Andre"	135	15	451	-
16	5.9	N71°08' E26°02'	"Karl-Viktor"	110	50	1650	386
"	"	" "	"Cato Andre"	135	42	180	113
17	6.9	N71°08' E26°02'	"Karl-Viktor"	110	62	-	-
"	"	" "	"Cato Andre"	135	60	683	73
18	6.9	N71°07' E26°04'	"Karl-Viktor"	110	53	37	6
"	"	" "	"Cato Andre"	135	50	135	18
19	7.9	N71°07' E26°04'	"Karl-Viktor"	110	60	-	-
"	"	" "	"Cato Andre"	135	55	659	11
20	7.9	N71°05' E26°03'	"Karl-Viktor"	110	55	756	193
"	"	" "	"Cato Andre"	135	65	1134	139
21	8.9	N71°05' E26°03'	"Karl-Viktor"	110	59	84	7
"	"	" "	"Cato Andre"	135	50	148	36
22	8.9	N71°05' E26°03'	"Karl-Viktor"	110	55	33	7
"	"	" "	"Cato Andre"	135	55	436	58
23	8.9	N71°05' E26°03'	"Karl-Viktor"	110	55	266	143
"	"	" "	"Cato Andre"	135	60	245	145
24	8.9	N71°05' E26°03'	"Karl-Viktor"	110	55	879	113
"	"	" "	"Cato Andre"	135	55	285	94
25	14.9	N71°05' E26°03'	"Cato Andre"	110	65	637	36
"	"	" "	"Karl-Viktor"	135	53	328	27
26	14.9	N71°05' E26°03'	"Cato Andre"	110	65	633	43
"	"	" "	"Karl-Viktor"	135	51	256	41
27	15.9	N71°05' E26°03'	"Cato Andre"	110	60	193	4
"	"	" "	"Karl-Viktor"	135	60	178	10
28	22.9	N68°27' E14°12'	"Cato Andre"	110	20	2	1
"	"	" "	"Karl-Viktor"	135	20	28	1
29	22.9	N68°38' E14°12'	"Cato Andre"	110	28	5	87
"	"	" "	"Karl-Viktor"	135	31	3	43
30	23.9	N68°38' E14°12'	"Cato Andre"	110	30	4	127
"	"	" "	"Karl-Viktor"	135	30	-	4

Table 2. Measurements of the Danish seine nets used in the experiments. (In each section, 10 meshes in 4 rows were measured. Standard ICES measuring gauge was used)

Date	110 mm net			135 mm net		
	Cod-end	Posterior mid-sect.	Anterior mid-sect.	Cod-end	Posterior mid-sect.	Anterior mid-sect.
20.8	110.3 mm	117.0 mm	120.2 mm	135.4 mm	137.0 mm	141.1 mm
28.8	112.1 mm	117.8 mm	122.5 mm	137.2 mm	138.4 mm	141.1 mm
3.9	110.8 mm	117.8 mm	121.6 mm	137.4 mm	138.0 mm	142.1 mm
10.9	111.4 mm	117.6 mm	121.6 mm	137.9 mm	138.5 mm	141.6 mm
17.9	110.6 mm	117.3 mm	120.4 mm	136.0 mm	138.5 mm	139.9 mm
22.9	110.7 mm	118.4 mm	120.8 mm	137.5 mm	138.0 mm	143.1 mm
Average	111.0 mm	117.6 mm	121.2 mm	136.9 mm	138.1 mm	141.5 mm

Table 3. Length distribution of cod at each station.

Length (cm)	Station / Mesh size																			
	1		2		3		4		5		6		7		8		9		10	
	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135
25-29																				
30-34	1															1				
35-39	14	7					14	2					2		1	5			1	
40-44	46	13	2	1	3		161	22	8			1	-		3	5		7	-	
45-49	42	23	6	-	5	1	259	68	20	1		10	17		3	2	2	4	3	11
50-54	34	25	59	7	34	2	567	153	108	9		25	56	39	2	1	-	7	11	48
55-59	17	30	106	10	56	2	644	193	311	34		26	131	69	-	2	2	19	10	164
60-64	5	21	119	13	65	11	637	172	365	74		41	188	252	2	-		14	11	295
65-69	6	19	104	23	43	6	427	95	289	86		31	153	352	4	-		5	4	251
70-74	1	10	34	8	18	2	105	25	149	50		9	68	162	1	1		2	-	128
75-79		4	13	2	15	1	56	3	50	17		2	35	63		-			1	57
80-84		-	3	-	8		35	1	24	15		3	10	57		-			1	39
85-89		1	1	-	3			1	12	2			4	9		-			-	11
90-94			1	-	1				4	1			5	21		-			1	-
95-99				-	2				4	-			1			-				6
100-				1						1						1				
Total	166	153	448	65	253	25	2905	735	1344	290	-	148	670	1024	16	18	4	58	43	1010

Table 3. Cod (continued).

Length (cm)	Station / Mesh size																			
	11		12		13		14		15		16		17		18		19		20	
	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135
25-29		1																		
30-34		1	1							1										
35-39	2	2	4	4	8		3		3	-										
40-44	3		17	5	17		8		25	3	19			4	1	2			4	2
45-49			14	12	34		9		58	24	80	16		19	5	12		6	40	4
50-54			11	12	34		21		84	82	342	37		54	12	28		46	152	89
55-59			18	15	43		7		52	113	451	35		166	11	43		130	214	183
60-64			18	25	18		14	2	26	98	347	48		210	3	32		198	173	377
65-69			4	16	5		7		15	95	260	31		139	5	12		174	98	298
70-74			7	5			1		3	28	120	8		50		5		67	45	109
75-79			2							7	12	3		20		1		20	16	32
80-84											13	1		9				12	4	22
85-89											6	-		5				2	4	8
90-94												-		5				4	4	4
95-99												1		-					2	2
100-														2						4
Total	5	4	96	94	159	-	70	2	266	451	1650	180	-	683	37	135	-	659	756	1134

Table 3. Cod (continued).

Length (cm)	Station / Mesh size																			
	21		22		23		24		25		26		27		28		29		30	
	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135
25-29																				
30-34									1											
35-39		1		4					2					1			1		1	
40-44		9	1	46			2		33	1	7		12	4		2	-		-	
45-49	3	13	6	116	3	7	40		93	9	20	6	28	8		1	1		-	
50-54	11	24	9	120	31	17	197	30	186	28	94	17	69	32		8	-		1	
55-59	25	42	9	77	63	40	230	71	172	74	182	44	49	45		9	-		-	
60-64	19	33	6	44	79	73	229	84	85	111	154	66	25	53		4	3	1	2	
65-69	14	18	2	21	66	43	100	60	36	74	111	72	7	25	2	1		1		
70-74	11	5		6	14	35	61	24	14	18	41	40	2	6		2		1		
75-79	-	2		2	6	12	12	9	11	7	14	7	1	2		1				
80-84	-	-			1	3	8	3	-	2	2	3		2						
85-89	-	1			3	4		3	3	-	4	1								
90-94	1					1		-	-	2	3									
95-99						2		-	1	1	-									
100-						8		1		1	1									
Total	84	148	33	436	266	245	879	285	637	328	633	256	193	178	2	28	5	3	4	-

Table 4. Length distribution of haddock at each station.

Length (cm)	Station / Mesh size																			
	1		2		3		4		5		6		7		8		9		10	
	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135
30-34																				
35-39			1													1	1			
40-44			15		1	1		2	1						3	4	1	1		
45-49			37	4	5	8	4	2	3	2		2	9	1	1	3	2	1	1	
50-54	1	8	106	19	10	9	19	4	14	3		5	8	4	2	1		-	5	1
55-59	-	1	134	28	4	15	25	11	31	14		22	18	16	1	2		-	6	1
60-64	2	3	128	40	15	28	8	5	51	18		3	33	33	2	1		1	12	12
65-69		3	112	48	18	40	6	3	43	43		3	29	65		2			7	18
70-74			28	12	5	23	1	1	8	15		1	3	20						9
75-79			2	2	1	1	1			1				3						
80-84																				
Total	3	15	563	153	59	125	64	28	151	96	-	36	100	142	9	14	4	3	31	41

Table 4. Haddock (continued).

Length (cm)	Station / Mesh size																			
	11		12		13		14		15		16		17		18		19		20	
	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135
30-34	9				1															
35-39	7		2	1	5															
40-44	2			-	16						7	1							5	
45-49				-	16						20	4				1			5	3
50-54				-	5						98	14		2	2	-		2	34	16
55-59				-	1						103	41		15	3	6		2	46	26
60-64				1							74	24		16	-	4		5	56	43
65-69											48	23		29	-	5		2	36	40
70-74											30	5		11	1	2			10	9
75-79											6	1							1	2
80-84																				
Total	18	-	2	2	44	-	-	-	-	-	386	113	-	73	6	18	-	11	193	139

Table 4. Haddock (continued).

Length (cm)	Station / Mesh size																			
	21		22		23		24		25		26		27		28		29		30	
	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135	110	135
30-34																				
35-39																	2.		2	
40-44	1				3	3	2		1		1						14	6	19	
45-49	3	1		1	14	13	8	3	6	2	2	2	1				38	18	58	1
50-54	2	5	1	6	31	19	28	12	7	5	10	6	1	1			24	9	38	1
55-59	1	11	3	12	34	35	29	23	4	8	13	17	1	5			5	6	9	-
60-64		11	2	16	39	38	23	22	5	9	8	8	1	2	1		3	2	1	1
65-69		3	1	17	20	25	22	27	8	2	7	7		2			1	2		1
70-74		4		6	2	12	1	6	5	1	2	-				1				
75-79		1						1				-								
80-84												1								
Total	7	36	7	58	143	145	113	94	36	27	43	41	4	10	1	1	87	43	127	4

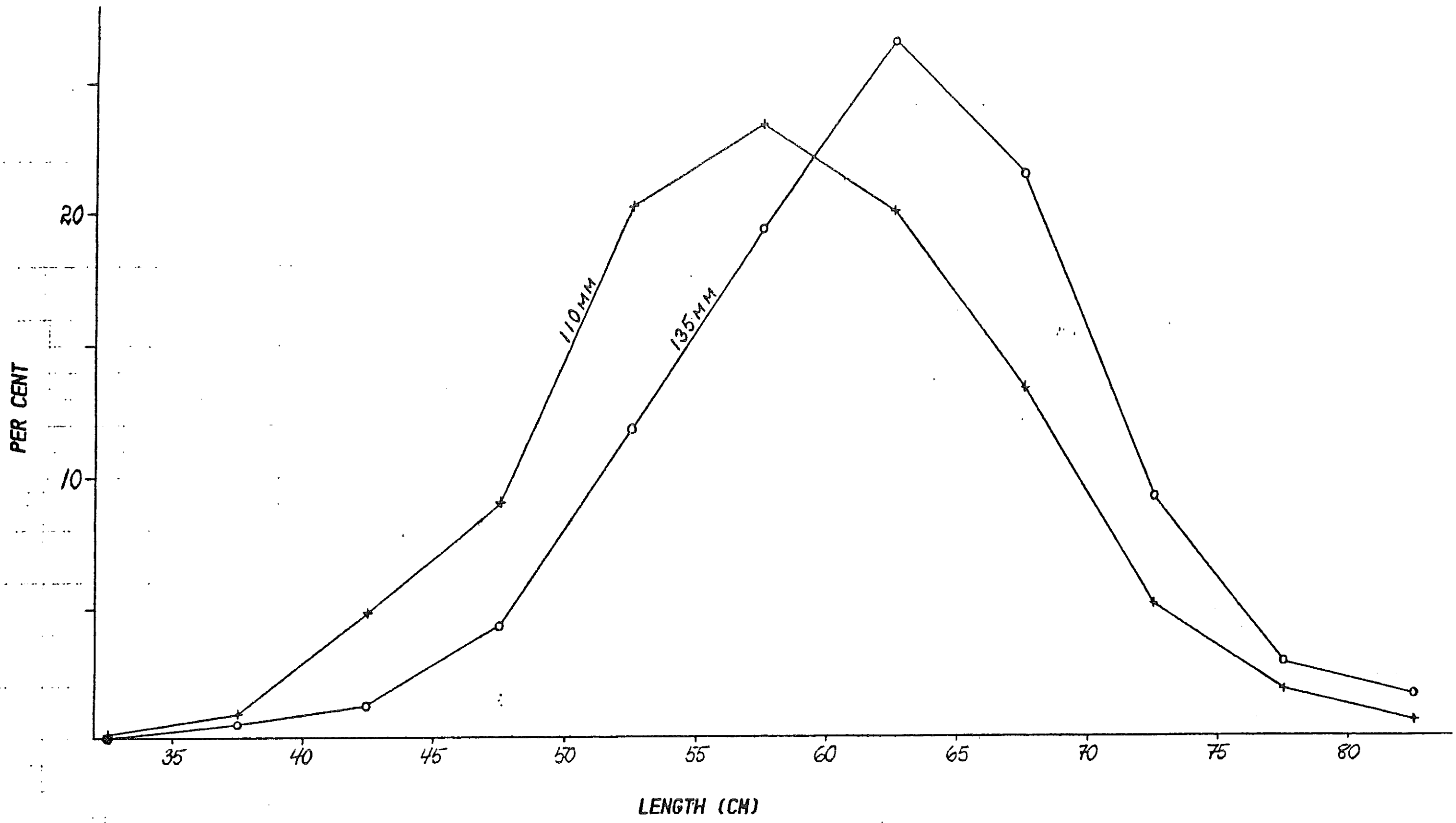

Figure 1. Length frequency distribution of cod caught with 110 mm and 135 mm mesh.
(Average frequencies for 12 stations with more than 100 cod caught in one of the nets.)

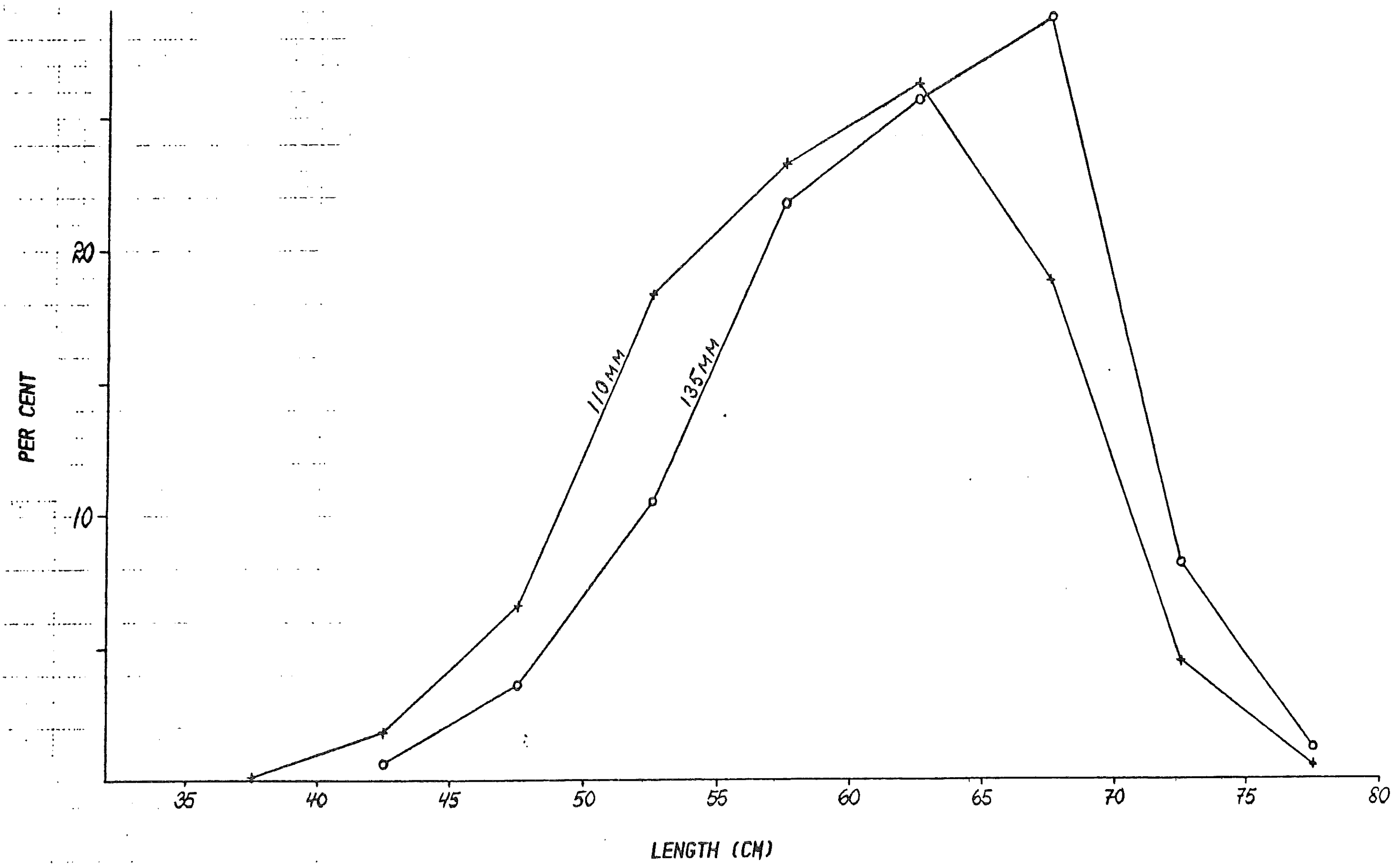

Figure 2. Length frequency distribution of haddock caught with 110 mm and 135 mm mesh.
(Average frequencies for 5 stations with more than 100 haddock caught in one of the nets.)

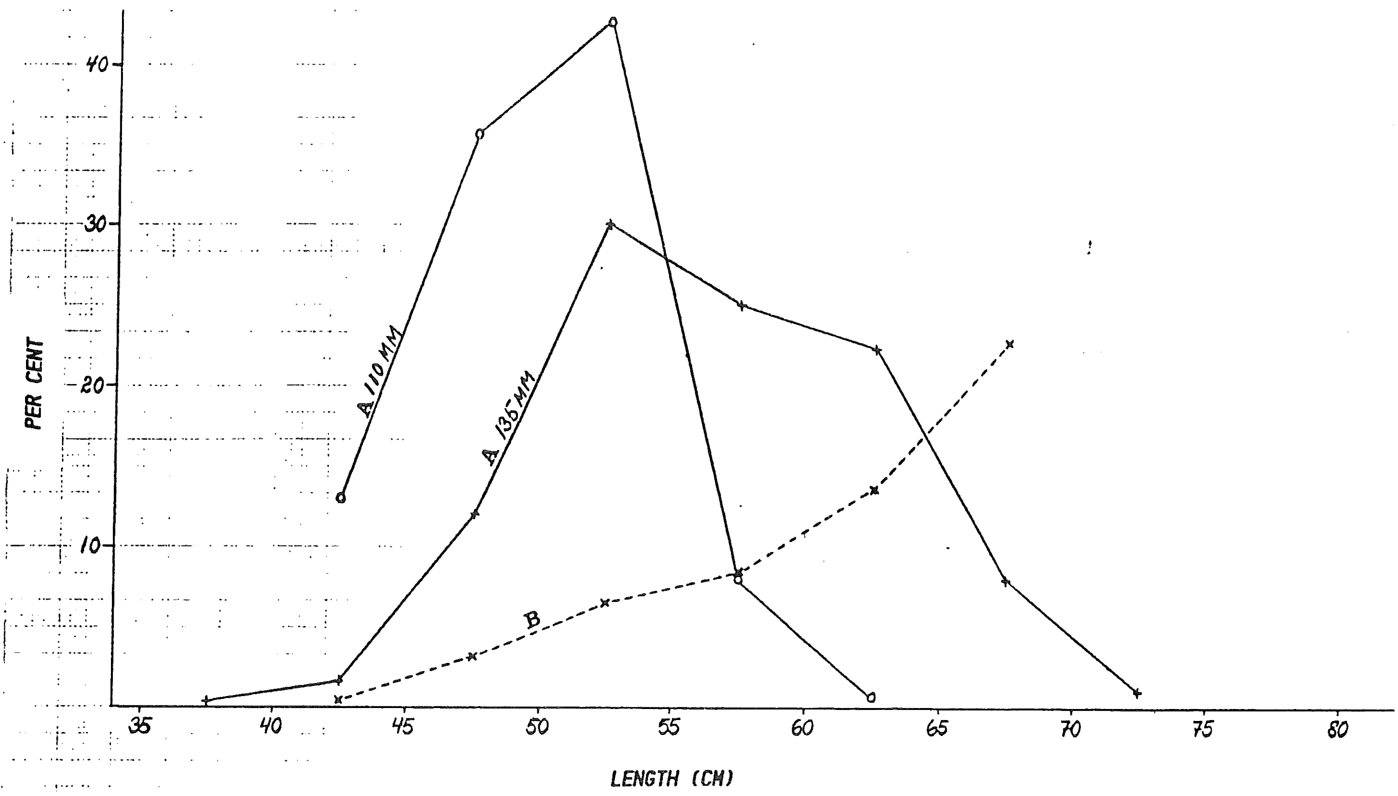

Figure 3. A. Length frequency distribution of cod stuck in the meshes of the 110 mm and 135 mm nets.
B. Cod stuck in the 135 mm meshes in per cent of the estimated numbers escaped.

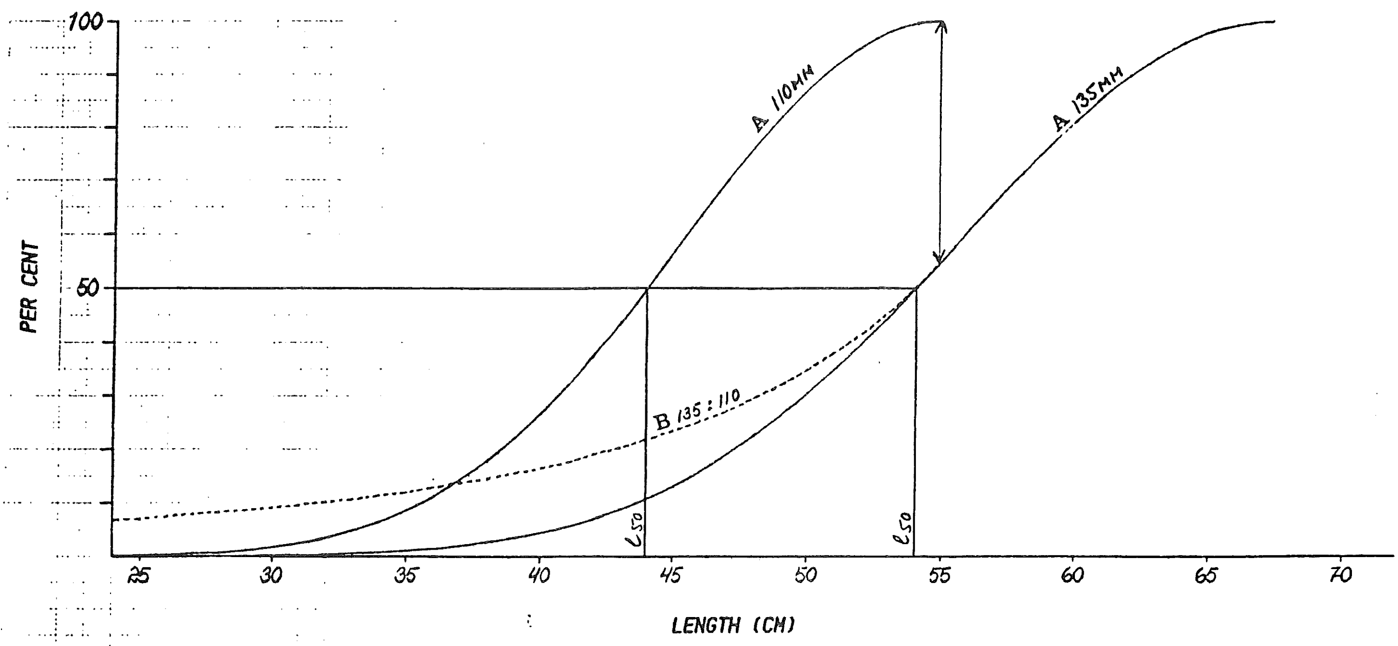

Figure 4. A. Examples of selection curves for 110 mm and 135 mm mesh size (S.F.=4.0).
B. The resulting relative selection curve (Catch 135mm / Catch 110 mm).

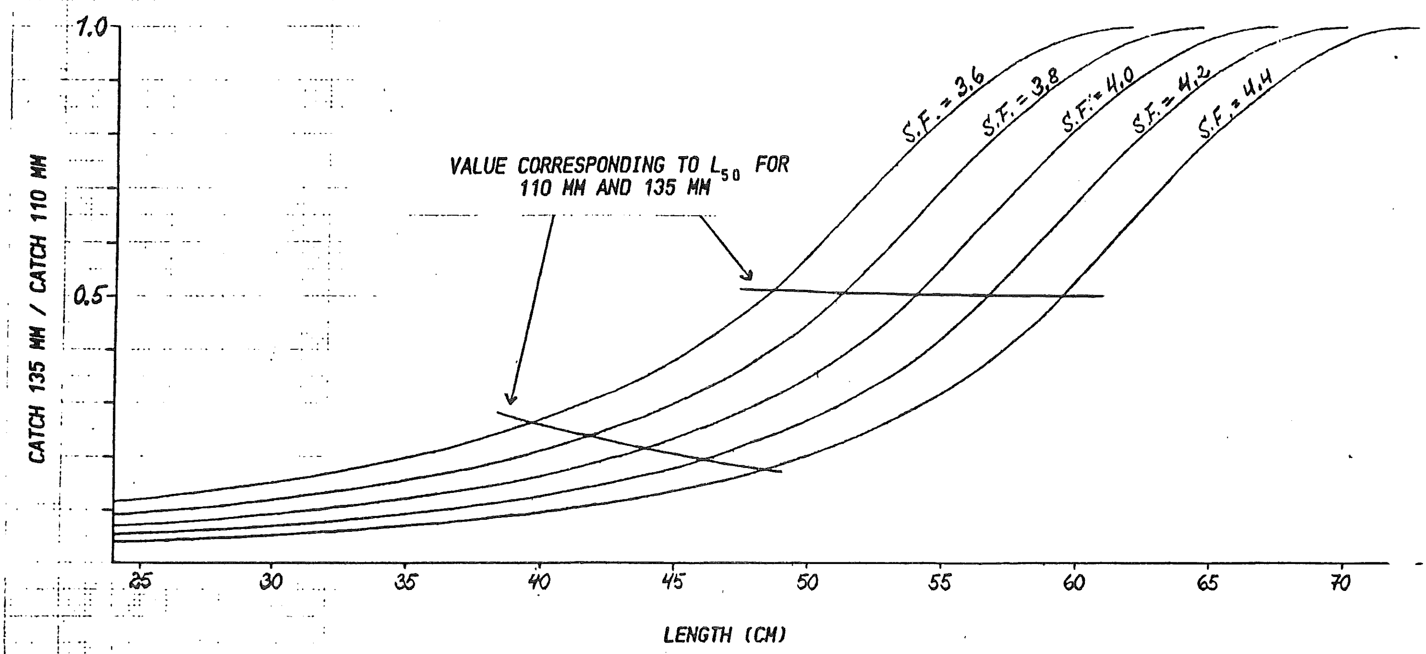

Figure 5. Examples of relative selection curves (135 mm/110 mm) for different selection factors (S.R.=10.0).

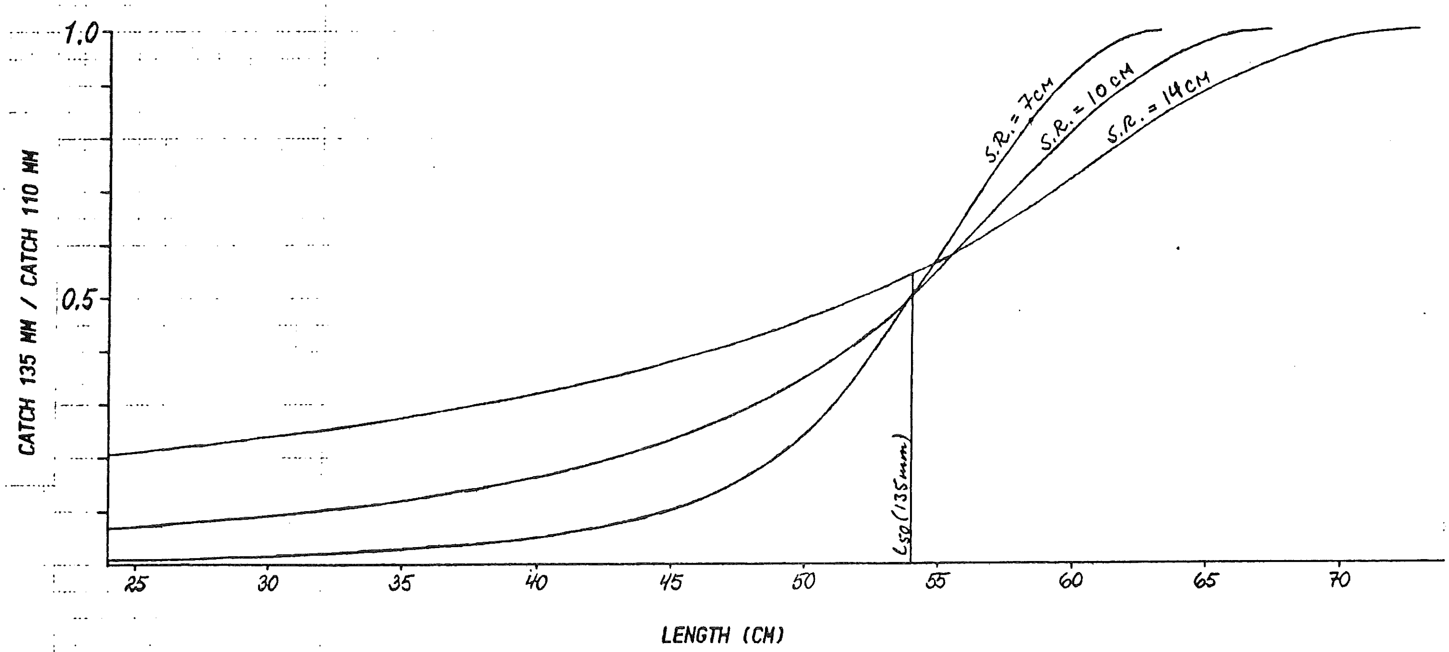

Figure 6. Examples of relative selection curves (135 mm/110 mm) for different selection ranges (S.F.=4.0).

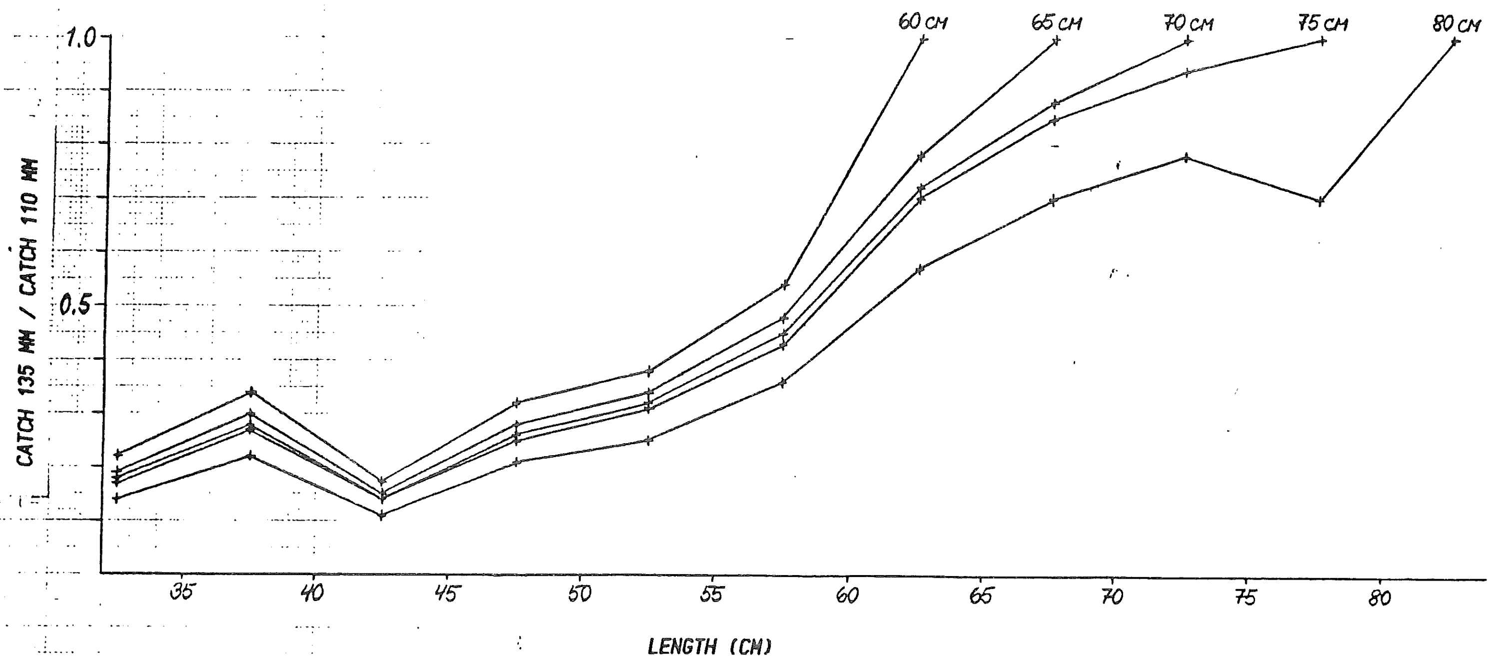

Figure 7. Ratio of catches of cod (relative selection curves) in the 135 mm and 110 mm nets for different assumptions of upper limit for the range of selection in the 135 mm net.

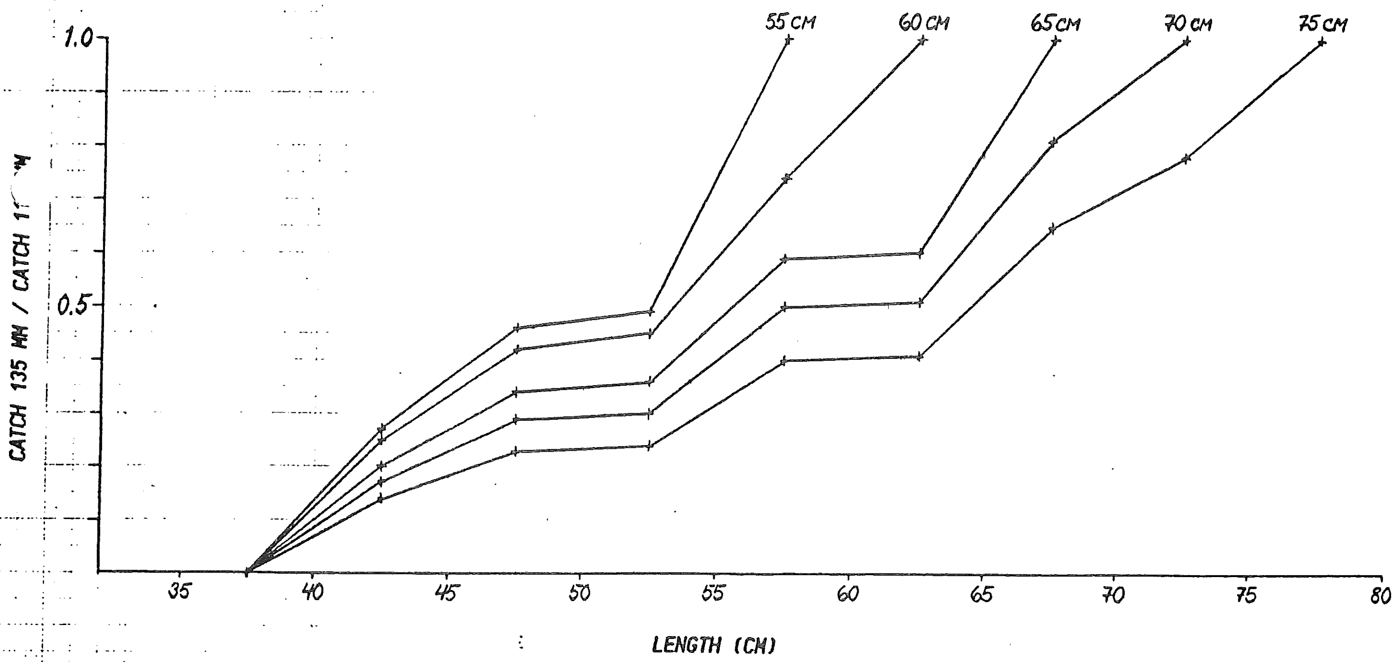

Figure 8. Ratio of catches of haddock (relative selection curves) in the 135 mm and 110 mm nets for different assumptions of upper limit for the range of selection in the 135 mm net.

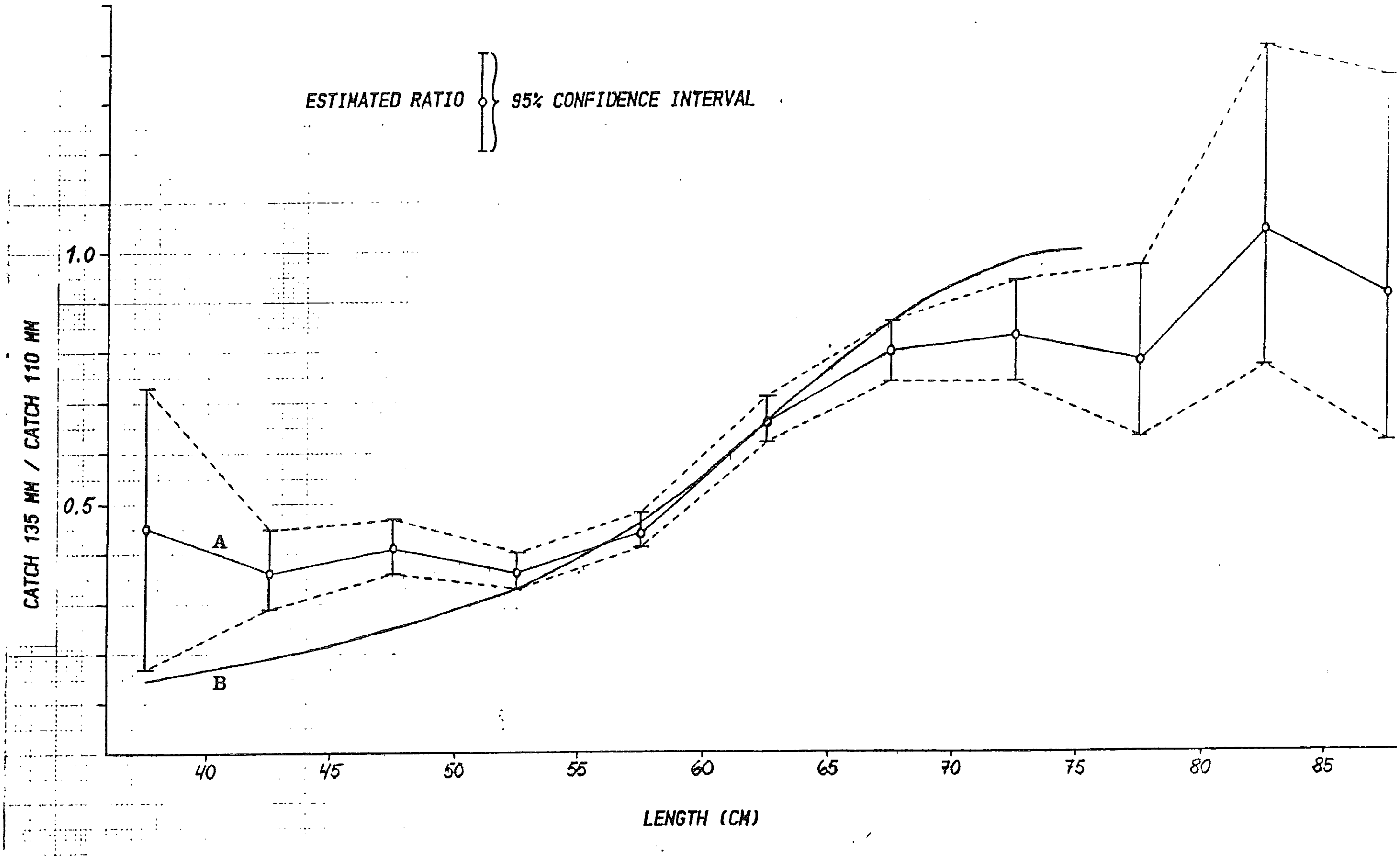

Figure 9. A. Relative selection curve (135 mm/110 mm) for cod from the variance analysis.
B. Curve assumed to give the best fit to the estimated values.

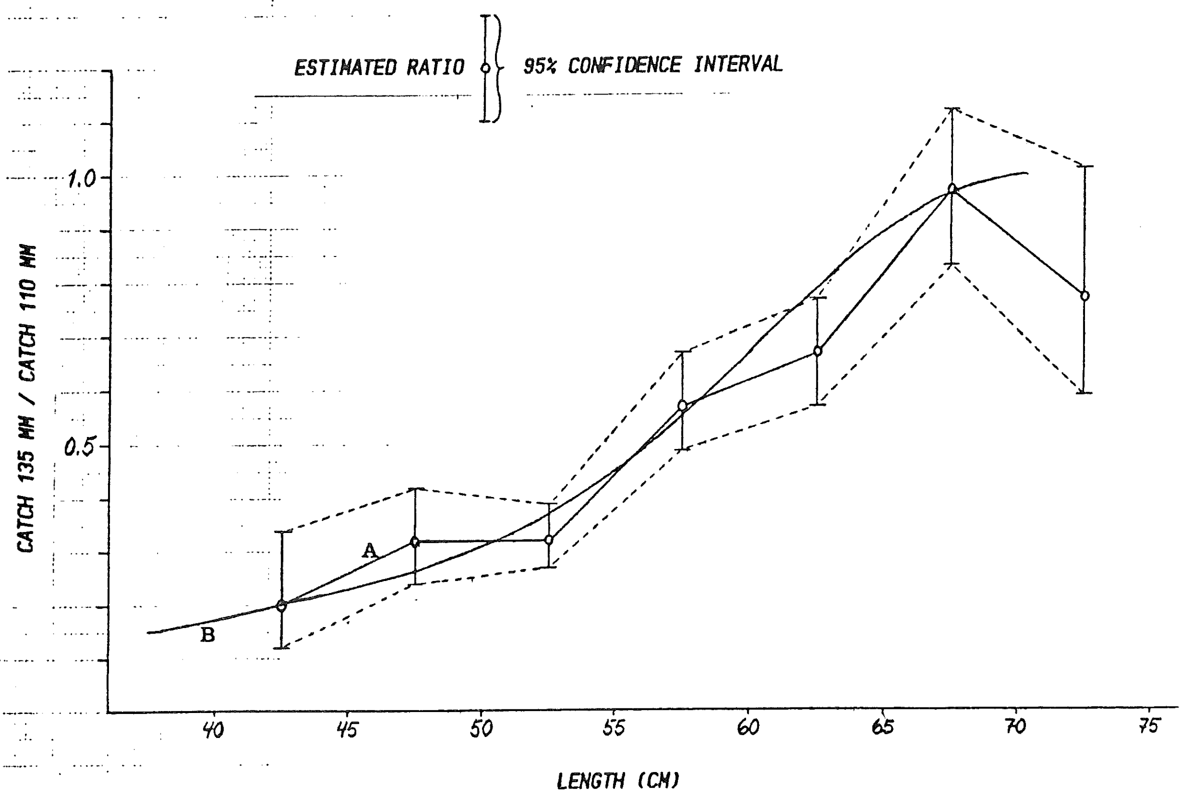

Figure 10. A. Relative selection curve (135 mm/110 mm) for haddock from the variance analysis.
B. Curve assumed to give the best fit to the estimated values.