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A Study of Selective Fishing Methods for the Northern Cod Otter Trawl Fishery

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December, 1993

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1934

Fisheries and Oceans Pêches et Océans

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Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. No. FS 97-6/ 1934 E Issn. 0706-6457

Correct Citation for this Publication:

Hickey, W.M., G. Brothers, Boulos, D.L., 1993, A Study of Selective Fishing Methods for the Northern Cod Otter Trawl Fishery. Can. Tech. Rep. Fish. Aquat. Sci. 1934: vi + 31.

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Hickey, W.M., Brothers, G., Boulos, D.L. 1993. A Study of Selective Fishing Methods for the Northern Cod Otter Trawl Fishery. Can. Tech. Rep. Fish. Aquat. Sci. 1934: vi + 31.

Otter trawl selection for Atlantic cod was studied using both the trouser trawl and covered codend methods during two commercial trips in January and February, 1992. The codend selection studies investigated methods of reducing the catch of undersized cod using the trouser trawl method with 155mm diamond mesh, 135mm square mesh, 135mm diamond mesh with lastridge ropes hung at 85%. A rigid grid system (Sort-X) with 50mm bar spacings was tested using a variation of the covered codend method whereby a 43mm retainer was placed over the Sort-X system and a 43mm codend used as a control. Selectivity parameters were estimated using the Select method (Millar and Walsh, 1992) for the trouser trawl experiments and a logistic regression procedure for the Sort-X system. For the mesh selectivity studies, both mesh alternatives to basic 155mm diamond mesh produced better selection characteristics. The 85% lastridge rope codend produced a selectivity range similar to the 135mm square mesh. The Sort-X system demonstrated variable results and large selection ranges. The selection factors were equivalent for all the mesh studies indicating that the short lastridge rope codends may be a viable alternative to an increase in diamond mesh or square mesh codends in the northern cod fishery.

RÉSUMÉ

Hickey, W.M., Brothers, G., Boulos, D.L. 1993. A Study of Selective Fishing Methods for the Northern Cod Otter Trawl Fishery. Can. Tech. Rep. Fish. Aquat. Sci. 1934: vi + 31.

On a étudié la sélection de la morue de l'Atlantique par des chaluts à panneaux en recourant à la méthode du chalut pantalon et à celle du cul-de-chalut recouvert, lors de deux sorties de pêche commerciale effectuées en janvier et février 1992. Il s'agissait d'évaluer divers moyens de réduire les prises de petite morue en utilisant des chaluts pantalons en filets constitués respectivement de mailles en losange de 155mm, de mailles carrées de 135mm, et de mailles en losange de 135mm avec ralingues à rapport d'armement de 85%. On a également fait l'essai d'un système de grille rigide (Sort-X) à barreaux espacés de 50mm, en recourant à une forme modifiée de la méthode du cul-de-chalut recouvert, c'est-à-dire en plaçant un filet de rétention à mailles de 43mm par dessus la grille Sort-X et en utilisant un cul-de-chalut témoin de 43mm. Dans le cas des expériences au chalut pantalon, les paramètres de sélectivé ont été estimés au moyen de la méthode Select (Millar et Walsh, 1992) et dans le cas du système Sort-X, ils l'ont été par une analyse de régression logistique. Pour ce qui est de la sélectivité des mailles, les deux maillages autres que le maillage de base en losange de 155mm ont donné de meilleurs résultats que ce dernier. Le cul-de-chalut doté de ralingues à rapport d'armement de 85% a produit une gamme de selectivité similaire à celle des mailles carrées de 135mm. Le système Sort-X a produit des résultats variables et une gamme de sélection élevée. Les facteurs de sélection étaient équivalents pour toutes les mailles considérées, ce qui indique que les culs-de-chalut à courte ralingue peuvent constituer une bonne solution de rechange à l'accroissement de la dimension des mailles en losange ou des mailles carrées des culs-de-chalut utilisés dans la pêche de la morue du Nord.

INTRODUCTION

The northern cod or 2j3kl fishery has been associated with extremely high catch rates since its beginning where hauls of 25 metric tonnes for only a 30 minute tow were quite common. These catches usually resulted in high discards and excessive handling due to the large quantity of undersized fish. Attempts to reduce catch sizes with gear modifications (i.e. windows and large diamond meshes) and acoustic catch control systems (i.e. scanmar) were found to be only partially successful (Kulka, 1989).

In the early 80's, efforts were being made to improve otter trawl selectivity (Robertson, 1982). Square mesh codends were the focus of these efforts and were reported to be more effective than traditional diamond mesh in releasing undersized round fish such as cod (Robertson, 1983; Isaksen and Valdemarsen, 1986; Larsson et al., 1988;). However, problems with handling and maintenance (Robertson, 1986; Cooper and Hickey, 1989) discouraged the acceptance of square mesh and this prompted further efforts to improve it and to develop other procedures to increase the selectivity of otter trawls.

One of the more promising methods used the placement of ropes laterally around the codend and/or the addition of lastridge ropes shorter than the stretched length of the codend to keep the meshes open and improve selectivity in the same manner as square mesh (Stewart and Robertson, 1985; Isaksen and Valdemarsen, 1990; Jacobson, 1991). A different approach used a rigid grate system, the Sort-X

system (Larsen and Isaksen, 1993), to reduce the catch of undersized fish before they entered the deeper areas of the codend.

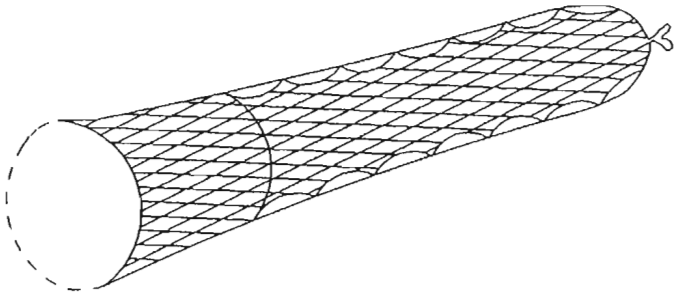
In the mid-80's, a number of studies were performed with square mesh codends in the northern cod fishery. In one of these, a comparison of codends made from either 135mm square mesh or 135mm diamond mesh, carried out during a commercial trip, indicated that the square mesh codend released more fish below 43cm than did the diamond mesh codend (Hearn, 1984). In addition, two large fish processing companies (Fisheries Products International (FPI) and National Sea Products Limited) attempted to adopt the use of square mesh codends when encountering small fish, however, the handling and maintainence problems associated with the square mesh discouraged its further use.

More recently, some work in the northern cod fishery has been performed with square and diamond mesh codends having mesh sizes ranging from 130mm to 155mm (Atkinson and Brothers, 1991) and with the Sort-X system having bar spacings of 50mm combined with a square mesh codend (Brothers, 1991). A small mesh control codend was not used with these mesh size studies and as such, selectivity parameters were not able to be determined. In contrast, the Sort-X system study used a small mesh codend over the grid outlet and a retainer bag over the square mesh codend which made it possible to estimate selection parameters for both the grate and the square mesh. The mesh size study of Atkinson and Brothers (1991) concluded that there was no difference in the selectivity of fish sizes among any of the codends tested, while the Sort-X study concluded that a combination of the Sort-

X system and a square mesh codend was more effective at releasing small fish than was either method employed alone.

This report describes the results of two commercial trips on an offshore trawler in 1992 and attempts to evaluate: (1) a 135mm square mesh codend; (2) two 135mm diamond mesh codends with lastridge ropes hung at 85% (Figure 1); (3) a 155mm diamond mesh codend; and (4) a Sort-X system with bar spacings of 50mm (Figure 2). The study focuses on assessing the relative selectivity characteristics of the various gear types tested.

Short Lastridge Rope Codend



Square Mesh Codend

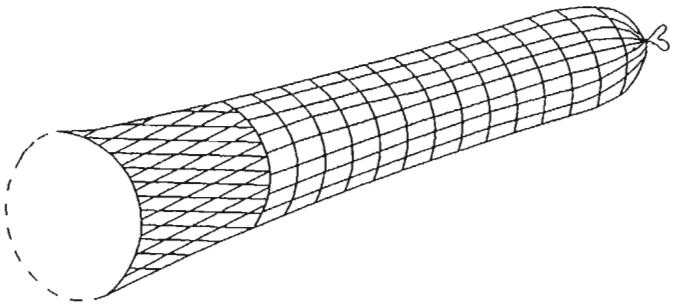


Figure 1: Short lastridge rope codend with diamond mesh and square mesh codend.

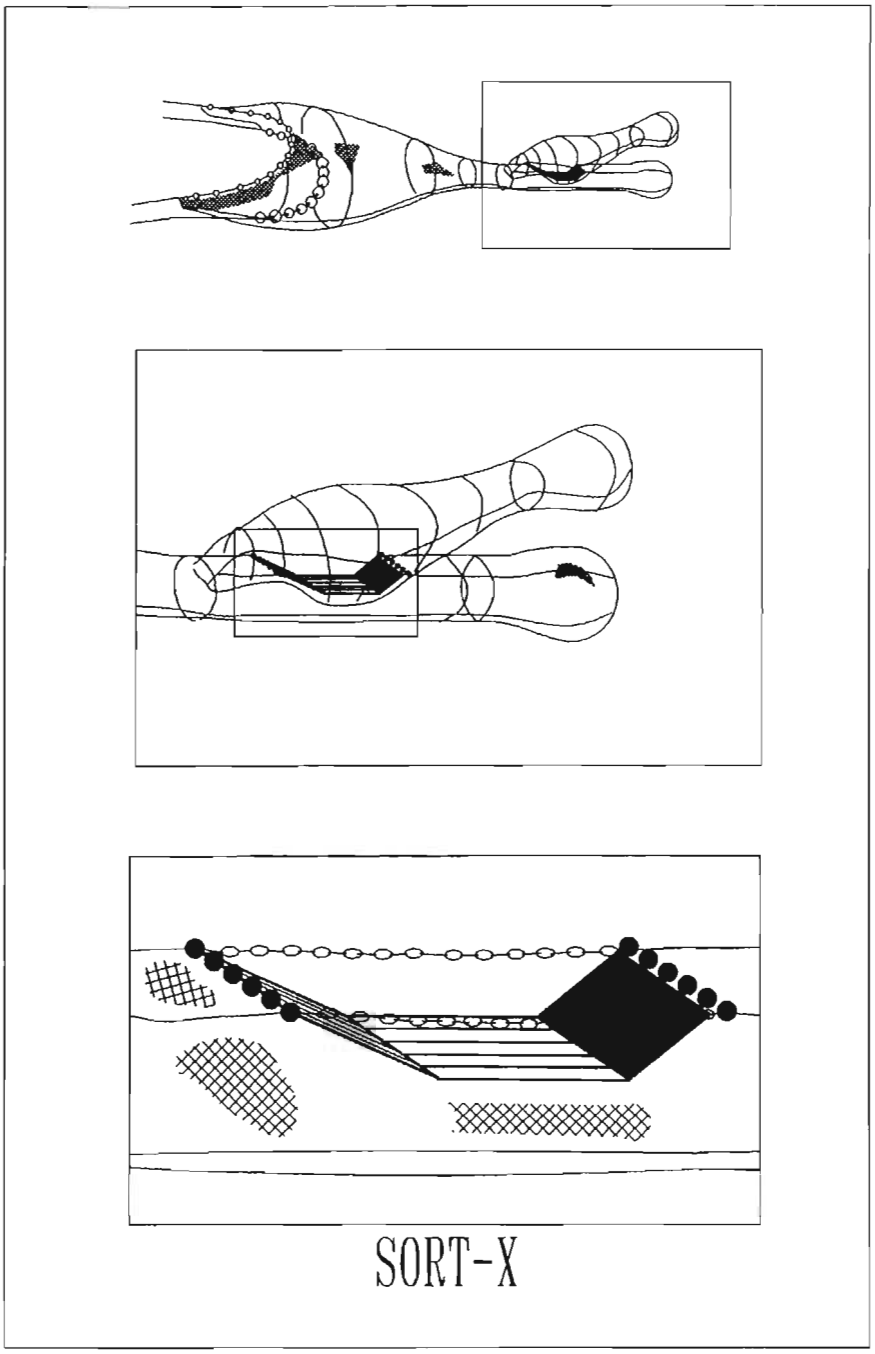


Figure 2: The Sort-X system with a retainer bag over the grid system.

MATERIALS AND METHODS

The M/V "ZANDVOORT", a 52 meter stern trawler, carried out two 10-day trips to NAFO sub-divisions 3kl (Figure 3) in January and February, 1992. This trawler is owned and operated by Fisheries Products International (FPI) and was commercial fishing while four different experiments were being conducted. The trawler used a 154' 8" Hampijhan hi-rise trawl (Figure 4) which was converted to a trouser trawl with a 45mm mesh vertical divider panel and twin codends. The footrope and headline lengths were 61 and 47m, respectively. The footrope contained 30 steel rollers from 40 to 60cm in diameter and the headline was floated with 80, 20cm (diameter) plastic floats. Mesh size was 160mm in the wings, square and first belly and 145mm in the twin extensions. Mesh measurements were usually carried out on the codends at regular intervals, however when temperatures were below freezing, measurements were not always taken.

The vertical panel was designed to divide the trawl into two equal sections, leading from the center of the headline and footrope to the twin extensions. These extensions, which accommodated the experimental and control codends, were often rotated to avoid possible side differences in the trouser trawl structure. This gear was designed using net parameters (e.g. headline height and wing spread) supplied by the manufacturer. The control codend was always 45mm (nominal 43mm) mesh.

All codends were fitted with lastridge ropes constructed from combination rope which was 25mm in diameter. The codends with lastridge ropes hung at 85% were

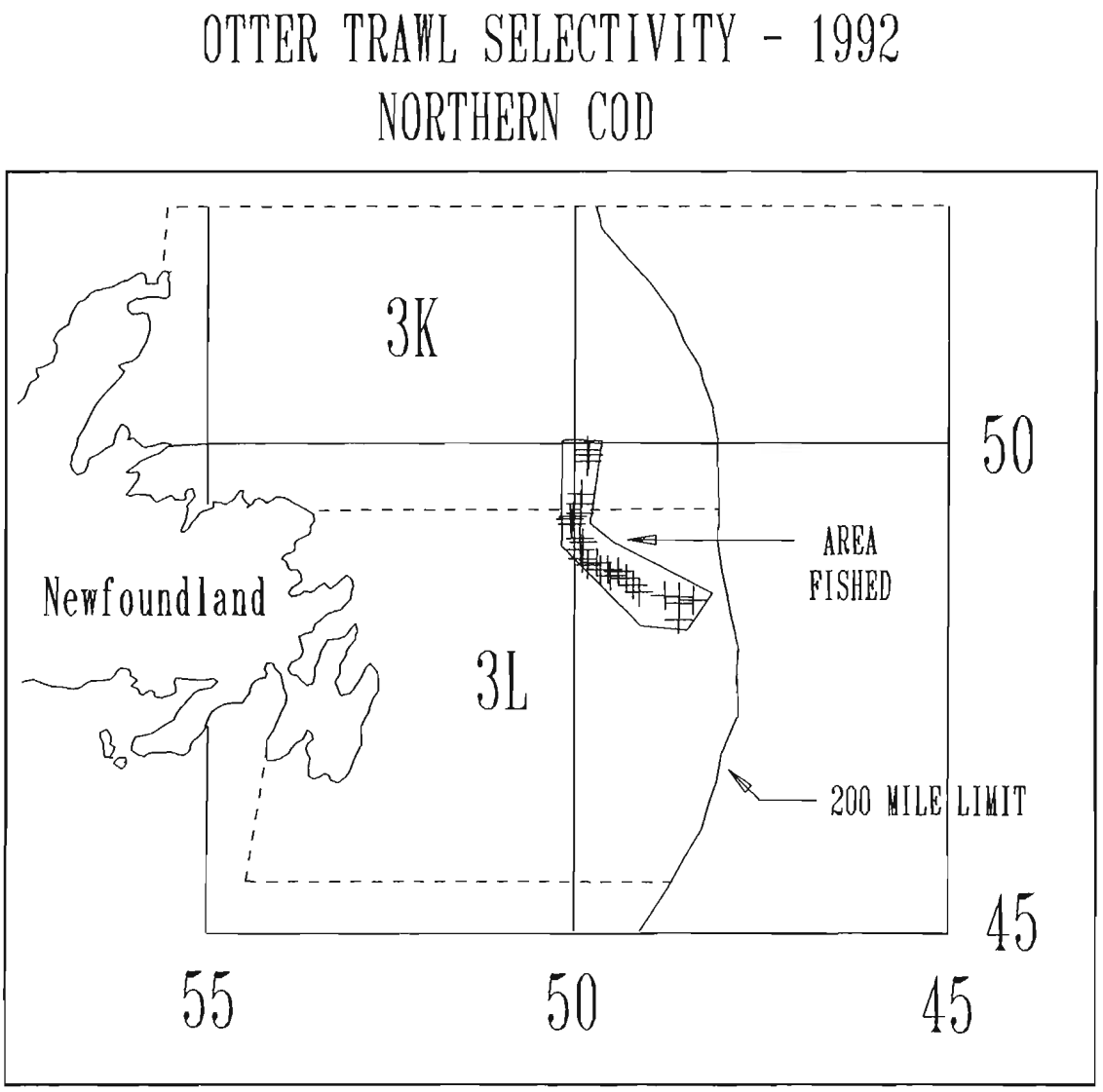


Figure 3: Study area for selectivity experiments conducted with the Sort-X system, square mesh, diamond mesh and short lastridge rope codends.

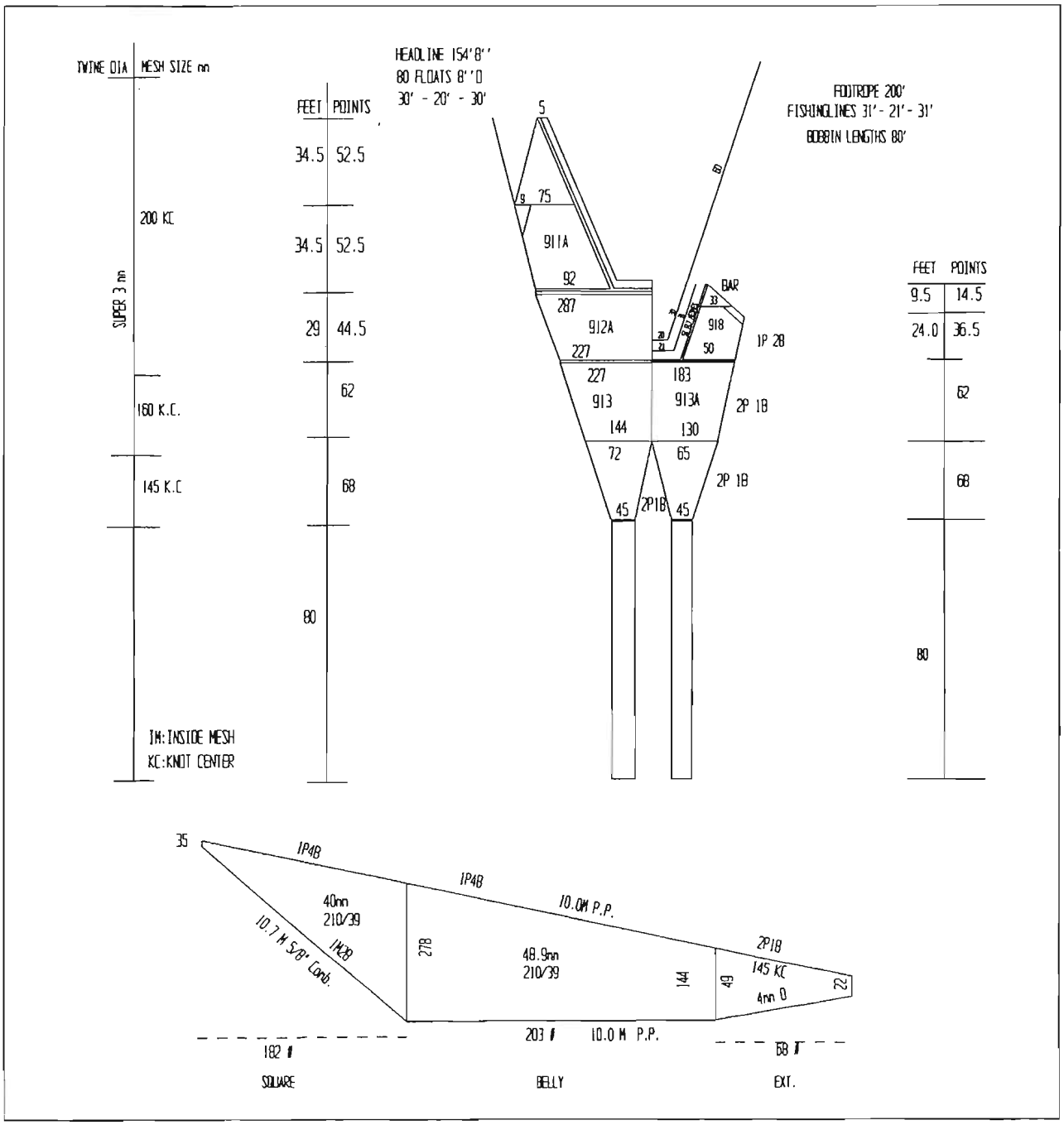


Figure 4: Schematic diagram of the Hampijhan 154′ 8" hi rise trawl.

attached using nylon ropes inserted through the combination rope and tied to the codend at 91cm intervals. Seizings were also placed halfway between the main stops as it was found that the stops slipped under heavy loads. However, codends with lastridge ropes hung at 100% had seizings placed at 91cm intervals along the combination rope only.

Three experiments were performed using the trouser trawl process. One leg of the trouser had 45mm mesh, while the other leg accommodated the experimental codend consisting of either 131mm square mesh (nominal 135mm), 149mm (nominal 155) diamond mesh, or 134mm (nominal 135) mesh with lastridge ropes hung at 85%. During the fourth experiment a Sort-X system was tested with an application of the covered codend method (Figure 2). This experiment used a retainer bag of 45mm mesh (nominal 43mm) placed over the fish outlet of the grid, while the codend consisted of 45mm mesh (nominal 43mm).

Sampling was conducted on all valid sets for both the control and the experimental codends. The sampling method used depended on the catch size and temperature. If temperatures were below freezing, visual estimates of the total catch for each codend were recorded on deck and samples were taken from each. The contents of both codends were then mixed together in the ramp and the accuracy of the total weights for the two codends, obtained from visual estimates, was later assessed by comparison with the total hold weight plus the total discard weight for that set. When temperatures were above freezing, a sample was taken from the experimental codend, either on deck or from the sorting belt. The catch from this

codend was then processed, while the control codend remained on deck. When processing of the experimental codend was completed, the discard weight and boxed fish hold weight were used to determine the total round weight for this codend. This procedure was then repeated for the control codend and the total weight for each codend was determined from the formula:

$$Tot.Wt.(kg) = \frac{1}{2.2} x (No.\ x\ 100\ x\ 1.2) + Dis(kg),$$

where 100lb is the weight of one box of fish, 1.2 is a factor to obtain round weight, No. refers to the number of boxes in the hold, Dis is the discard weight and 2.2 is the pound to kilogram conversion factor.

Cod, *Gadus morhua*, were measured to the nearest 1cm fork length and subsequently grouped into 3cm length intervals for analysis. Atlantic cod was the only species of fish caught and as such all analyses pertain to it. Sample weights were obtained by applying an average basket weight to the number of baskets.

Two DFO representatives performed sampling and supervised all modifications and repairs to experimental gear with assistance from the ship's crew. A set and catch data sheet was completed for all sets and included information on set time, depth, position, course, speed, weather information as well as comments on net damage or gear changes.

Selectivity curves were obtained for the data from the trouser trawl studies using the Select method of Millar and Walsh (1992). The parameter estimates for the

Select method were produced using a maximum likelihood procedure (i.e. Gauss-Newton method). Multiple sets were analyzed both individually and combined. The sets were combined using a method similar to that performed by Suuronen and Millar (1992) where the length distributions for separate sets were factored up or down using the estimated splits to artificially give an equal split between codends prior to combining sets to produce a common selectivity curve. This artificial factoring was performed to partially alleviate any influence of an unequal proportion split between sets on the estimation of the combined selectivity characteristics.

Selectivity curves for the Sort-X system experiment were generated using a maximum likelihood logistic regression procedure and multiple sets were analyzed both individually and combined.

The relationship between the calculated L50 and catch weight of individual sets was examined to determine if catch size produced an influence on selectivity. This relationship was investigated using Spearmans rank correlation coefficient and was performed for all experiments. Catch weight for the trouser trawl studies was determined from the total weight within the small mesh codend and the proportion split of each set. The catch weight for the Sort-X system consisted of the total catch within both the retainer bag and the codend.

RESULTS

Four experiments were conducted in January and February of 1992 during the two trips to NAFO sub-divisions 3kl (Figure 3) on the M/V "ZANDVOORT". These experiments (Table 1) were carried out in water depths ranging from 445 to 834 meters with tow lengths varying from 20 minutes to 1 hour 20 minutes. In all, 48 sets were performed, 29 of which were successful and used in the analysis. The catch for the sets ranged from 1,060 to 31,176kg of cod and the total for the two trips was 363,389kg.

Table 1: Cruise details for the three trouser trawl and Sort-X system experiments.

Cruise No.	Date	Codend Type	Mesh Opening (mm)		Construction		Twine	
			Nomimal	Measured	Meshes/ Bars Long	Meshes/ Bars Round	Diameter (mm)	Single/Double Polyethylene Construction
1	Jan. 20, 1992 To Jan. 29, 1992	Square Mesh	135	131	340 Bars	105 Bars	5 Braided	Double
		Diamond Mesh	155	149	160 Meshes	95 Meshes	5 Braided	Double
		Control	43	45	550 Meshes	320 Meshes	1.5 Twisted	Single with Cover
2	Jan. 31, 1992 To Feb. 09, 1992	85% Lastridge Ropes	135	134	170 Meshes	320 Meshes	5.5 Braided	Double
		Sort-X Retainer	43	45	250 Meshes	500 Meshes	1.5 Twisted	Single with Cover
		Control	43	45	550 Meshes	320 Meshes	1.5 Twisted	Single with Cover

Note: The Hampijhan 154' 8" hi-rise trawl was used for each of the above cruises and both cruises took place in NAFO division 3KL.

TRIP # 1

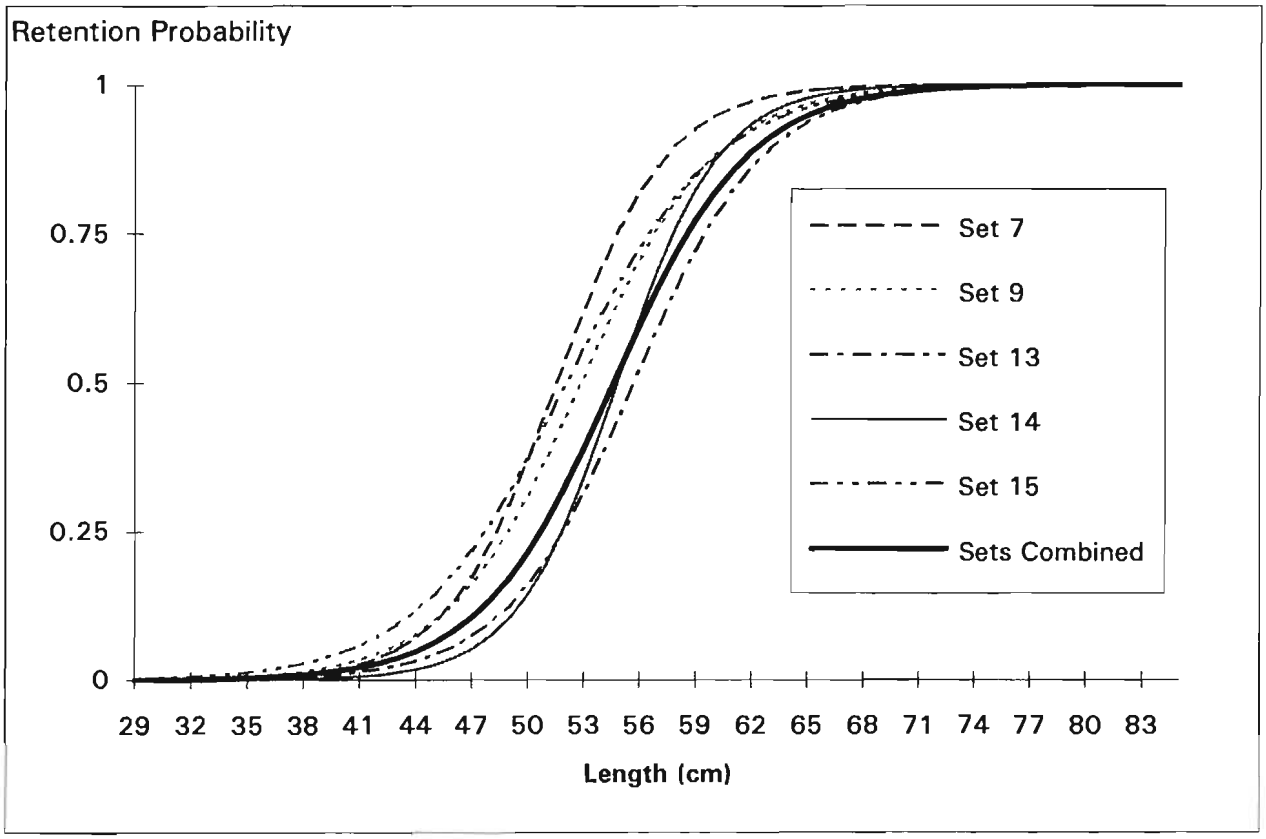
Experiment # 1: 131mm Square Mesh Versus a 45mm Control

Five successful sets were performed with the 131mm square mesh codend. The total catch weighed 48,164kg and ranged from 2,727 to 15,272kg (Table 2) for the five individual sets. Fish lengths for the combined sets ranged from 26 to 80cm in the control codend and from 34 to 81cm for the experimental codend. The mean fish length was 42.6cm in the small mesh codend, while it was 51.9cm in the experimental codend. The percentage of fish caught that were below 43cm was 8.00% for the experimental codend (Table 2). The L50, selection range and selection factor for the individual sets ranged from 52.2 to 56.0cm, 6.0 to 8.9cm and 4.0 to 4.3, respectively (Figure 5). Combined, the sets produced an L50 of 55.2cm, a selection range of 7.9cm and a selection factor of 4.2. There was no significant relationship found between the L50 and catch weight ($r = 0.40$, $p = 0.505$).

Table 2: Summary of catch results for the experiment using 131mm square mesh vs. 45mm diamond mesh.

Set Number	*Codend Mesh Size (mm)	Number Caught	Length Range (cm)	Mean Length (cm)	Total Catch (kg)	Average Weight of Fish (kg)	% of Fish Below 43cm
7	131S	479	39-81	54.03	682	1.42	1.8
	45D	2149	33-80	46.48	2045	0.95	30.1
9	131S	1464	35-71	50.15	1636	1.12	9.8
	45D	19462	30-68	42.34	13636	0.70	55.7
13	131S	3167	37-77	52.38	4076	1.29	6.9
	45D	10174	29-72	42.34	8702	0.86	38.6
14	131S	589	39-77	54.92	886	1.50	1.7
	45D	8042	26-66	42.20	5744	0.71	56.7
15	131S	1196	34-67	50.32	1511	1.26	14.3
	45D	13484	30-69	42.88	9246	0.69	55.5
Sets Combined	131S	6895	34-81	51.88	8791	1.27	8.0
	45D	53311	26-80	42.58	39373	0.74	51.5

* D = diamond mesh, S = square mesh



	131mm Square Mesh					
	Set 7	Set 9	Set 13	Set 14	Set 15	Sets Combined
a	-17.54(1.40)	-14.81(0.50)	-16.16(0.31)	-20.29(0.90)	-13.03(0.52)	-15.30(0.20)
b	0.34(0.03)	0.28(0.01)	0.29(0.01)	0.37(0.02)	0.25(0.01)	0.28(0.01)
p	0.49(0.03)	0.38(0.02)	0.78(0.02)	0.56(0.03)	0.39(0.03)	0.51(0.01)
L50	52.2	52.2	56.0	55.6	53.0	55.2
L25	49.0	48.3	52.2	52.6	48.5	51.2
L75	55.5	56.0	59.9	58.6	57.5	59.1
S.R.	6.5	7.7	7.6	6.0	8.9	7.9
S.F.	4.0	4.0	4.3	4.2	4.0	4.2

Figure 5: Atlantic cod selectivity curves and parameter estimates for separate and combined sets using 131mm square mesh.

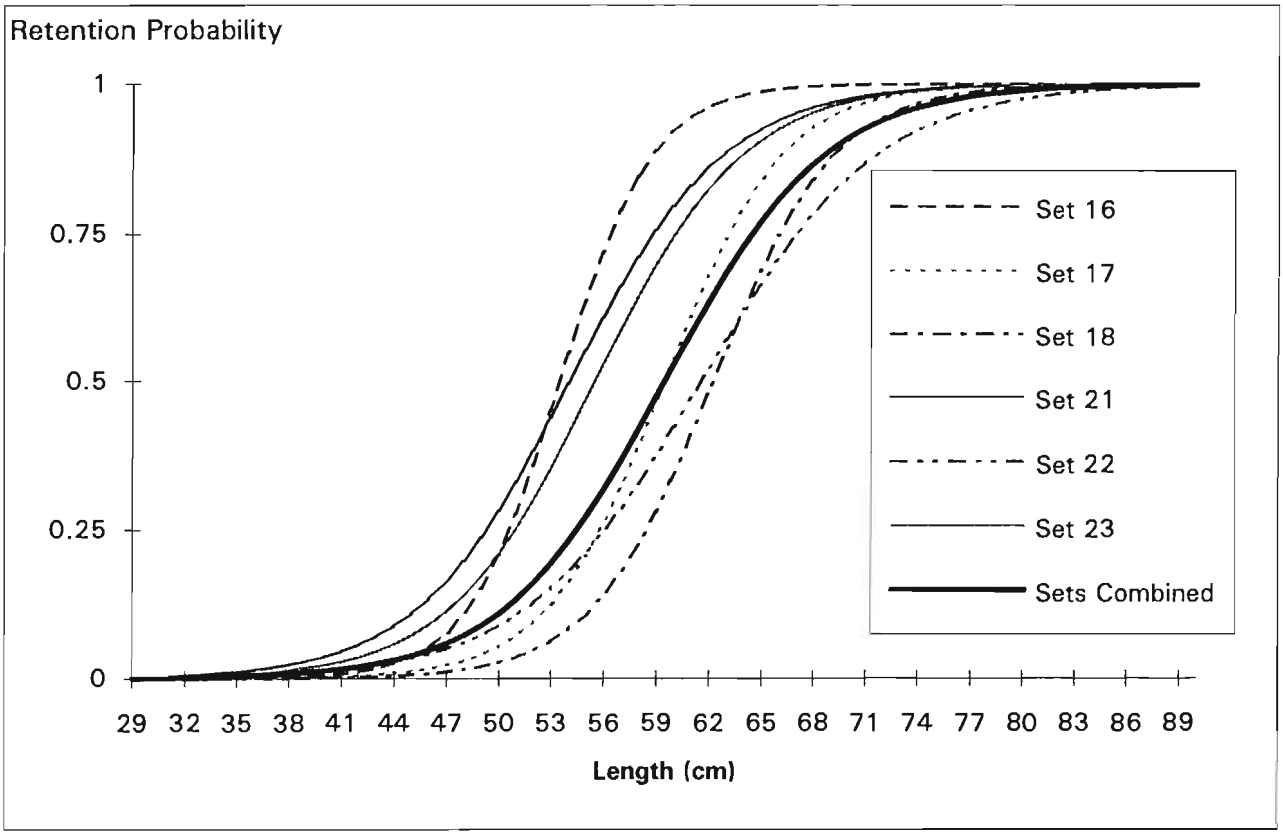
Experiment # 2: 149mm Diamond Mesh Versus a 45mm Mesh Control

Six successful sets were performed with the 149mm diamond mesh codend. The total catch weighed 39,132kg and ranged from 1,960 to 11,480kg (Table 3) for the six individual sets. Fish lengths for the sets combined ranged from 28 to 76cm in the small mesh codend and from 36 to 89cm for the experimental codend. The average length of fish was 47.0cm in the control codend, while it was 55.6cm in the experimental codend. The percentage of fish caught that were below 43cm in the experimental codend was 3.32% (Table 3). The L50, selection range and selection factor for individual sets ranged from 53.3 to 63.0cm, 5.8 to 11.0cm and 3.6 to 9.2, respectively (Figure 6). It appears that the largest selection range of 11.0cm corresponds to the set which had the largest catch. Combined, the sets produced an L50 of 60.8cm, a selection range of 10.2cm and a selection factor of 4.1. There was a significant relationship found between the L50 and catch weight ($r = 0.89$, $p = 0.0188$). This relationship was such that the L50 tended to increase with an escalation in catch weight.

Table 3: Summary of catch results for experiment using 149mm diamond mesh vs. 45mm diamond mesh.

Set Number	*Codend Mesh Size (mm)	Number Caught	Length Range (cm)	Mean Length (cm)	Total Catch (kg)	Average Weight of Fish (kg)	% of Fish Below 43cm
16	149D	211	39-86	56.48	418	1.98	0.95
	45D	1314	31-66	47.29	1542	1.17	23.2
17	149D	384	41-81	59.19	697	1.82	0.52
	45D	5945	34-70	47.72	6606	1.11	24.9
18	149D	442	41-89	58.01	792	1.79	0.90
	45D	8973	28-71	45.41	7662	0.85	32.9
21	149D	954	37-82	53.67	1306	1.37	6.22
	45D	7036	31-76	46.23	6321	0.90	32.2
22	149D	1237	36-75	55.89	2045	1.65	2.04
	45D	8321	34-73	48.57	9435	1.13	18.5
23	149D	403	38-69	52.71	569	1.41	6.95
	45D	1893	34-70	46.33	1739	0.92	25.7
Sets Combined	149D	3631	36-89	55.64	5827	1.60	3.32
	45D	33482	28-76	46.90	33305	0.99	26.97

* D = diamond mesh, S = square mesh



	149mm Diamond Mesh						
	Set 16	Set 17	Set 18	Set 21	Set 22	Set 23	Sets Combined
a	-20.34(2.45)	-17.85(1.06)	-18.06(0.70)	-12.44(0.71)	-12.32(0.46)	-13.33(1.02)	-13.09(0.25)
b	0.38(0.05)	0.30(0.02)	0.29(0.02)	0.23(0.02)	0.20(0.01)	0.24(0.03)	0.22(0.01)
p	0.42(0.04)	0.41(0.04)	0.61(0.05)	0.38(0.02)	0.56(0.04)	0.61(0.06)	0.51(0.02)
L50	53.3	59.9	63.0	53.5	61.8	56.4	60.8
L25	50.4	56.2	59.2	48.8	56.3	51.8	55.8
L75	56.1	63.6	66.9	58.2	67.3	61.1	65.9
S.R.	5.8	7.4	7.7	9.4	11.0	9.3	10.2
S.F.	3.6	4.0	4.2	3.6	4.1	3.8	4.1

Figure 6: Atlantic cod selectivity curves and parameter estimates for separate and combined sets using 149mm diamond mesh.

TRIP # 2

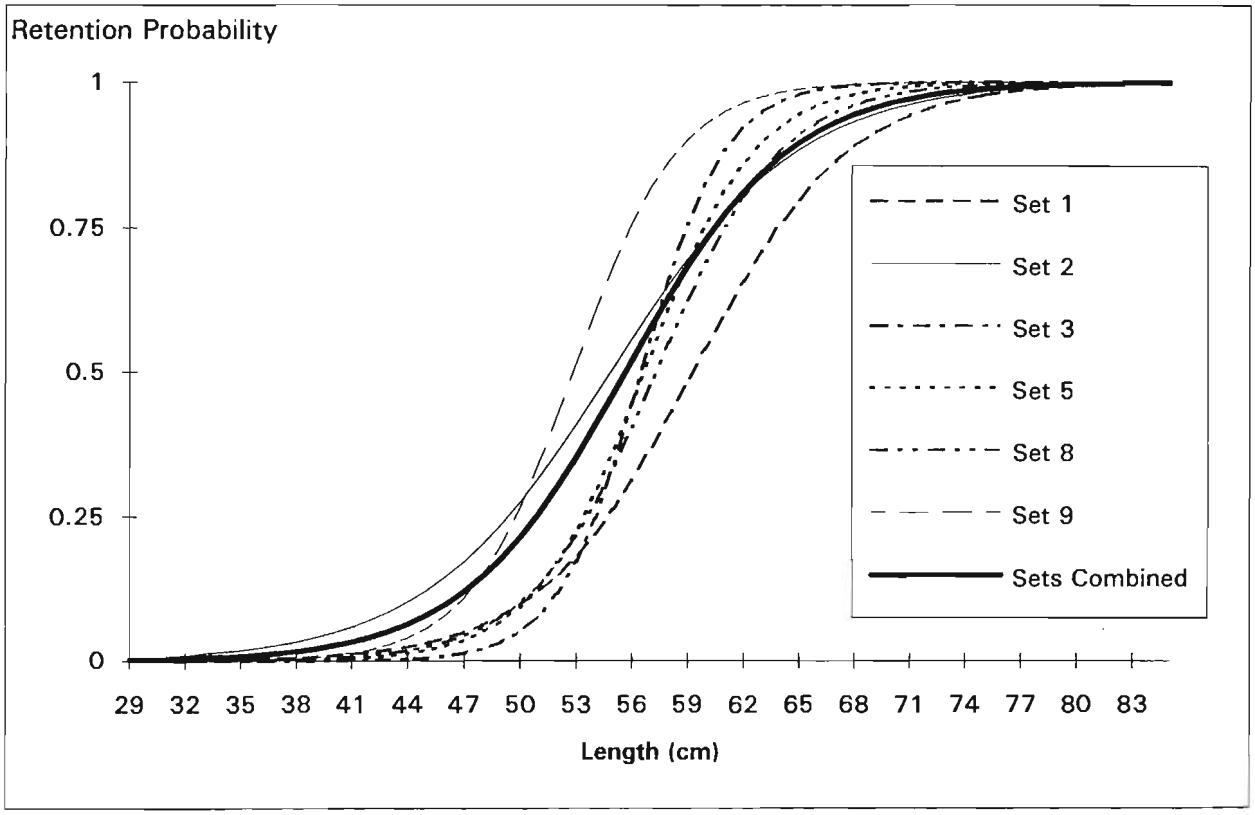
Experiment # 3: 134mm Diamond Mesh with 85% Lastridge Ropes Versus a 45mm Control

Six successful sets were performed using the 134mm diamond mesh codend with lastridge ropes hung at 85%. The total catch weighed 75,070kg and ranged from 1,468 to 29,908kg for the six individual sets (Table 4). Fish lengths for the sets combined ranged from 30 to 78cm in the control codend and from 36 to 85cm for the experimental codend. The average length of fish was 48.2cm in the small mesh codend, while it was 54.5cm in the experimental codend. The percentage of fish caught in the experimental codend that were below 43cm was 2.20% (Table 4). The L50, the selection range and the selection factor for individual sets ranged from 52.2 to 58.2cm, 4.8 to 11.1cm and 3.9 to 4.3, respectively (Figure 7). It appears that the largest selection range of 11.1cm corresponds to the set which had the largest catch. Combined, the sets produced an L50 of 56.2cm, a selection range of 9.6cm and a selection factor of 4.2. There was no significant relationship found between the L50 and catch weight ($r = -0.09$, $p = 0.8717$).

Table 4: Summary of catch results for the experiment using 134mm diamond mesh with 85% lastridge ropes vs. 45mm diamond mesh.

Set Number	*Codend	Number Caught	Length Range (cm)	Mean Length (cm)	Total Catch (kg)	Average Weight of Fish (kg)	% of Fish Below 43cm
1	85%	2342	36-73	54.35	3573	1.53	2.32
	43D	7958	35-78	47.24	7560	0.95	22.19
2	85%	9479	38-78	53.78	13243	1.40	2.94
	43D	15785	33-68	48.32	16665	1.06	15.54
3	85%	803	45-85	59.14	1527	1.90	0
	43D	4751	30-73	50.65	5279	1.11	9.91
5	85%	212	42-74	56.54	370	1.75	0.47
	43D	1092	31-71	47.31	1098	1.01	23.24
8	85%	1353	40-77	56.18	2078	1.54	1.01
	43D	9118	33-75	47.82	9745	1.07	17.5
9	85%	2139	40-74	54.61	3273	1.53	0.57
	43D	10659	35-67	48.17	10659	1.00	19.47
Sets Combined	85%	16328	36-85	54.47	24064	1.47	2.20
	43D	49363	30-78	48.22	52533	1.06	17.45

* D = diamond mesh, % = lastridge rope hanging ratio on 134mm diamond mesh



	Lastridge Ropes Hung at 85%						
	Set 1	Set 2	Set 3	Set 5	Set 8	Set 9	Sets Combined
a	-14.23(0.42)	-10.97(0.27)	-25.42(1.64)	-19.26(1.85)	-17.19(0.67)	-19.02(0.81)	-12.80(0.18)
b	0.24(0.01)	0.20(0.01)	0.45(0.03)	0.34(0.04)	0.30(0.01)	0.36(0.02)	0.23(0.01)
p	0.71(0.02)	0.71(0.01)	0.42(0.02)	0.61(0.06)	0.51(0.02)	0.41(0.01)	0.51(0.01)
L50	58.2	55.4	56.0	56.8	56.8	52.2	56.2
L25	53.7	49.9	53.6	53.6	53.2	49.1	51.4
L75	62.7	61.0	58.4	60.0	60.4	55.2	61.0
S.R.	9.0	11.1	4.8	6.5	7.3	6.0	9.6
S.F.	4.3	4.1	4.2	4.2	4.2	3.9	4.2

Figure 7: Atlantic cod selectivity curves and parameter estimates for separate and combined sets using 134mm diamond mesh with lastridge ropes hung at 85%.

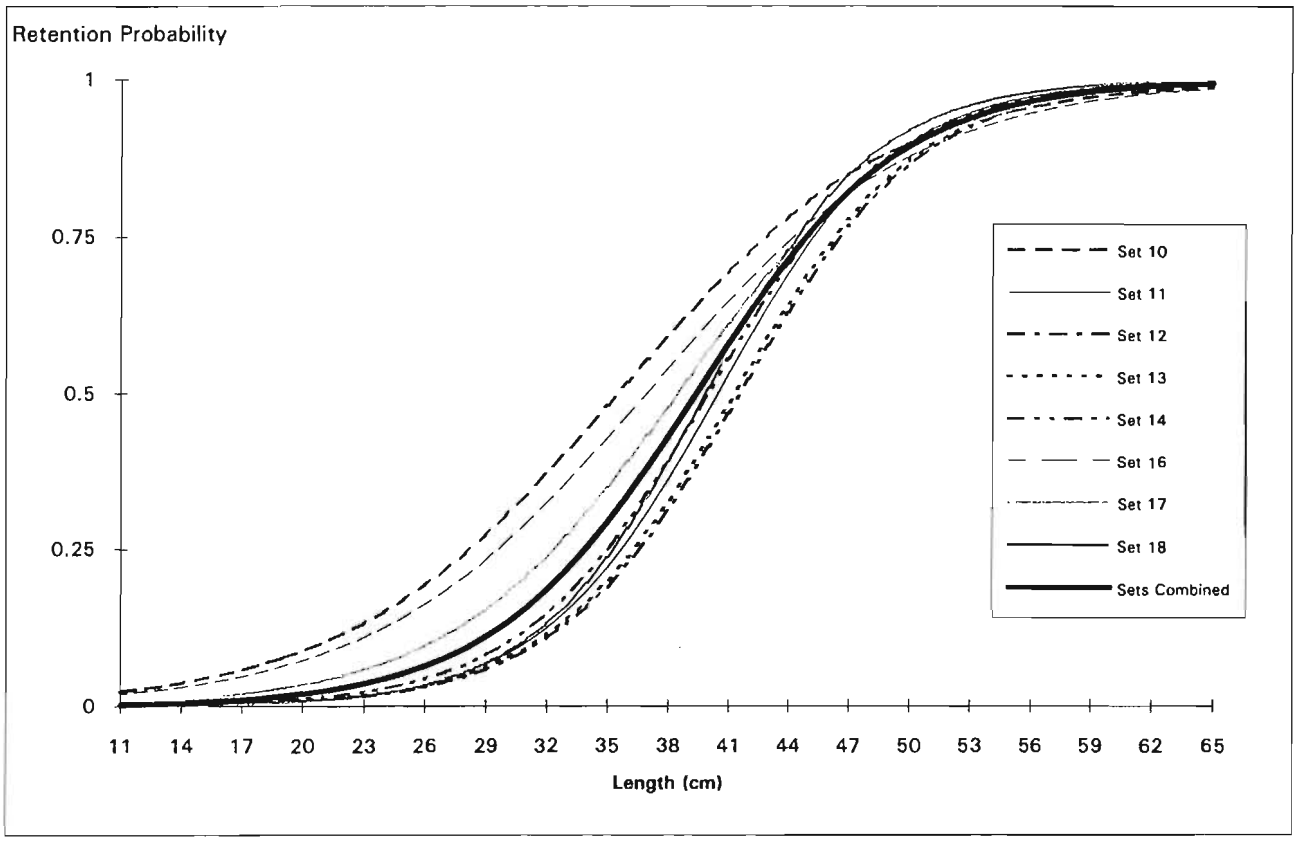
Experiment # 4: A Sort-X System of 50mm bar spacing, with a 45mm Control Codend and a 45mm Retainer Bag

Eight sets were performed using the Sort-X system on a 45mm diamond mesh codend with a 45mm mesh retainer bag over the outlet from the grid system. The total catch for all sets weighed 138,964kg and ranged from 4,911 to 31,176kg over the eight individual sets (Table 5). Length for the sets combined ranged from 27 to 57cm in the retainer bag and from 31 to 75cm for the codend. The average length of fish in the retainer bag was 42.5cm, while it was 47.8cm for the codend. The percentage of fish below 43cm that were caught in the codend was 19.54%, as compared to 48.57% for the retainer bag (Table 5). This appears to indicate that approximately 50% of the fish released by the Sort-X system are below 43cm. The L50 and selection range for the individual sets varied from 36.5 to 41.5cm and 9.1 to 15.0cm, respectively (Figure 8). Combined, the sets produced an L50 of 39.6cm and a selection range of 11.0cm. There appears to be no significant relationship between the L50 and catch weight ($r = 0.14$, $p = 0.7358$) when using the Sort-X system.

Table 5: Summary of catch results for the experiment using a Sort-X system with a 45mm control codend and a 45mm retainer bag (RB) over the grate.

Set Number	*Codend	Number Caught	Length Range (cm)	Mean Length (cm)	Total Catch (kg)	Average Weight of Fish (kg)	% of Fish Below 43cm
10	RB	4389	32-57	44.15	3637	0.83	38.62
	43D	18297	35-85	48.77	19861	1.09	16.33
11	RB	3231	31-51	42.74	2232	0.69	46.67
	43D	8464	37-69	47.90	8213	0.97	16.44
12	RB	1886	30-54	42.59	1239	0.66	50.14
	43D	4058	34-65	47.19	3672	0.90	19.94
13	RB	4936	27-56	42.70	3336	0.68	47.49
	43D	11619	33-69	48.58	11368	0.98	12.50
14	RB	7889	31-53	42.62	5537	0.70	48.02
	43D	20714	35-69	47.33	18971	0.92	20.30
16	RB	2030	31-55	41.48	1206	0.59	61.24
	43D	5067	31-69	45.50	4462	0.88	34.25
17	RB	8058	32-56	41.94	5059	0.63	56.10
	43D	22011	32-74	47.50	18995	0.86	24.49
18	RB	8780	33-57	41.95	5687	0.65	45.17
	43D	27166	34-75	47.84	25489	0.94	18.27
Sets Combined	RB	41199	27-57	42.47	27933	0.68	48.57
	43D	117396	31-85	47.79	111031	0.95	19.54

* Codend mesh size (mm). D = diamond mesh and RB = retainer bag.



	Sort-X System with 50mm Bar Spacings								
	Set 10	Set 11	Set 12	Set 13	Set 14	Set 16	Set 17	Set 18	Sets Combined
a	-5.33(0.16)	-9.31(0.26)	-9.15(0.34)	-9.09(0.19)	-8.08(0.16)	-5.54(0.26)	-6.93(0.13)	-9.57(0.15)	-7.88(0.06)
b	0.15(0.01)	0.23(0.01)	0.22(0.01)	0.22(0.01)	0.22(0.01)	0.15(0.01)	0.18(0.01)	0.24(0.01)	0.20(0.01)
L50	36.5	40.7	41.2	41.5	40.3	37.2	38.8	39.8	39.6
L25	29.0	35.9	36.3	36.5	35.3	29.8	32.6	35.2	34.0
L75	44.0	45.5	46.2	46.5	45.4	44.6	44.9	44.3	45.1
S.R.	15.0	9.6	9.9	10.0	10.1	14.8	12.3	9.1	11.0

Figure 8: Atlantic cod selectivity curves and parameter estimates for separate and combined sets using the Sort-X System with 50mm bar spacings.

DISCUSSION

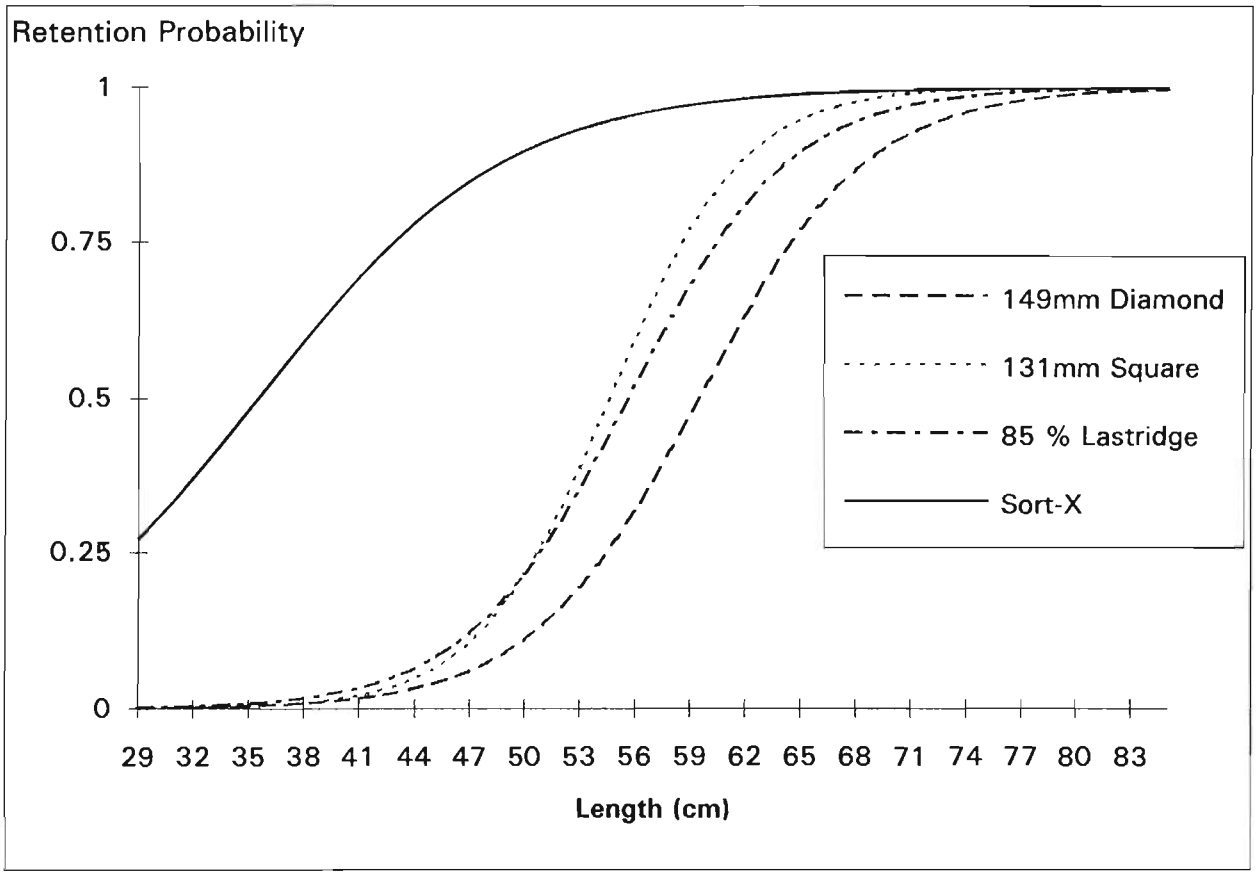
It is not unusual for the nominal mesh size of netting which is used in the construction of otter trawls to vary from the actual measured size. This variability has been found between manufacturers and between bales of netting from the same manufacturer. However, the mesh sizes measured during this project indicated variability that was greater than normal for all experiments. The mesh size measurements for the nominal 135mm square mesh codend ranged from 110 to 136mm with an average of 131mm. The nominal 155mm diamond mesh codend measurements ranged from 140 to 153mm, producing an average of 149mm. Measurements on the nominal 135mm diamond mesh with lastridge ropes hung at 85% ranged from a mesh size of 126 to 144mm and resulted in an average of 134mm. This variability may have been caused by the conditions under which measurements were occasionally taken (i.e. freezing temperatures) or, in the case of square mesh, stretching of the panels prior to construction. However while mesh sizes varied, it is believed that the comparisons between codends were still applicable since mesh sizes tend to vary as stretching and weathering occurs with normal use.

The experiments with the square mesh codend and the lastridge ropes hung at 85% were found to have similar L50's and selection factors (Figures 5 and 7). These results are similar to what has previously been found by Isaksen and Valdemarsen (1990) in their comparison of 85-88% lastridge rope codends with square mesh codends. It is believed that lastridge ropes not only open the diamond meshes to work like square mesh, but also help to promote escape behaviour. Fish escapement for

both square and diamond mesh codends occurs immediately in front of the accumulating catch (Pers. Obs.). When shortented lastridge ropes are attached to the codends at 46cm intervals, undulations form in the netting when it is being fished and these provide visual barriers for the codend's occupants. These barriers appear to stimulate escape behaviour in the fish throughout the codend's length (Isaksen and Valdemarsen, 1990).

In contrast, the individual sets using the 149mm diamond mesh codend showed much greater variability in its selectivity characteristics as was demonstrated by a generally higher L50, a longer and more variable selection range and a slightly lower selection factor as compared to either the 131mm square mesh or the 134mm diamond mesh with lastridge ropes hung at 85% (Figure 9). These results indicate that shortened lastridge rope codends and square mesh codends produce better selection characteristics than 149mm diamond mesh codends and Sort-X systems with 50mm bar spacings.

The experiments using the Sort-X system with a grid of 50mm bar spacing (Figure 8) differed somewhat from what was reported by Larsen et al. (1993) using a 55mm grid. While it appears that the Sort-X system does help to release some small fish, its selectivity characteristics would indicate that it is not very efficient at doing so. The L50's and selection ranges for individual sets of this study were quite variable, the L50 was generally lower and the selection range was always higher than what was previously reported. The catches were found to contain many more small fish than expected from previous work with the Sort-X system (Brothers, 1991;



	149mm Diamond	131mm Square	85 % Lastridge	Sort-X
a	-13.09(0.25)	-15.30(0.20)	-12.80(0.18)	-7.88(0.06)
b	0.22(0.01)	0.28(0.01)	0.23(0.01)	0.20(0.01)
p	0.51(0.02)	0.51(0.01)	0.51(0.01)	-
L50	60.8	55.2	56.2	39.6
L25	55.8	51.2	51.4	34.0
L75	65.9	59.1	61.0	45.1
S.R.	10.2	7.9	9.6	11.0
S.F.	4.1	4.2	4.2	-

Figure 9: Atlantic cod selectivity curves and parameter estimates for combined sets using 131mm square mesh, 149mm diamond mesh, 134mm diamond with lastridge ropes hung at 85% and the Sort-X System with 50mm bar spacings.

Larsen et al., 1991). Our results, in contrasting dramatically with previous work on the Sort-X system, would suggest some anomalies with it which may partly be due to a portion of the catch entering the codend without contacting the grate, small fish re-entering the extension from the retainer bag by way of the grid and possibly an inability of the system to handle large catches.

The possibility of a relationship between the L50 and catch weight was investigated across the sets for each experiment. A significant relationship was found for only the 149mm diamond mesh codend and this association was such that the L50 tended to increase with higher catch weights. This result was possibly caused by the same factors that produced the noticeable variability between individual sets for the diamond mesh study and may not reflect a true association between the L50 and the catch weight.

One disadvantage was encountered while using shortened lastridge ropes and this involved maintaining the lastridge rope to codend hanging ratio. This problem was not solved during the course of this study and requires further investigation. A definite advantage with using short lastridge ropes was the absence of a problem with knot slippage, as is typically encountered with square mesh codends (Cooper and Hickey, 1989). In addition, short lastridge rope codends do not appear to roll on deck as has been seen for square mesh codends (Pers. Obs).

It appears that shortened lastridge ropes may be a viable alternative to diamond mesh increases and troublesome square mesh codends. However, more work is necessary to determine the best lastridge rope to codend hanging ratio and to

determine if there are changes in selection range associated with increasing mesh sizes, particularly with shortened lastridge ropes.

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