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By-Catch Reduction in the Northern Shrimp Fishery

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ABSTRACT

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A 60-meter commercial shrimp vessel equipped with two standard shrimp trawls was used to test trawl selectivity equipment in 54 days of experimental fishing off northeast Newfoundland and southern Labrador during the winter of 1993. One trawl was rigged with experimental devices, including Nordmore Grates with 22mm, 25mm, and 28mm bar spacings, and a 43mm square mesh codend. A Scanmar monitoring system was used to measure door spreads, headline heights, grate angles and through-grate water flows. The two trawls were fished alternately for 24-hour periods. In a separate experiment, a retainer bag placed over the fish outlet was used with the 22mm grate to capture escaping fish. All three grates reduced by-catch levels by approximately 60% to 99%, depending on species. During comparative fishing, shrimp catches/hour were generally much lower when the Nordmore grate was used. The retainer bag experiment averaged 19.4% shrimp loss. Lost shrimp were slightly larger than those retained. Comparative fishing using the square mesh codend and a 43mm diamond mesh codend yielded respective catches averaging 121 and 130 shrimp/kg.

RÉSUMÉ

Hickey, W.M., Brothers, G., and Boulos, D.L., 1993. By-Catch Reduction in the Northern Shrimp Fishery. Can. Tech. Rep. Fish. Aquat. Sci. 1964: vi + 41

Un crevettier commercial de 60 mètres équipé de deux chaluts à crevettes standard a été utilisé pour éprouver des dispositifs de sélectivé des chaluts au cours d'une pêche expérimentale de 54 jours, pratiquée durant l'hiver 1993 au large du nord-est de Terre-Neuve et du sud du Labrador. Un des chaluts était muni de dispositifs expérimentaux, dont des grilles Nordmore à barreaux placés respectivement à intervalles de 22 mm, 25 mm et 28 mm et un cul-de-chalut à mailles carrées de 43 mm. Un système de surveillance Scanmar permettait de mesurer l'écartement des panneaux, la hauteur de la ralingue supérieure, l'angle de la grille et le courant passant à travers celle-ci. Les deux chaluts ont été utilisés à tour de rôle pendant des périodes de 24 heures. De plus, une expérience distincte a été réalisée avec la grille à écartement de 22 mm et un sac placé au-dessus de l'orifice d'évasion du poisson pour intercepter ce dernier. Il s'est avéré que les trois grilles ont permis de réduire les prises accidentelles de 60% à 99% environ, selon les espèces. Les prises de crevettes à l'heure étaient généralement beaucoup plus basses avec le chalut muni de la grille Nordmore. Dans le cas où on a eu recours à un sac de rétention, les pertes de crevettes se chiffraient à 19,4%; en outre, les crevettes perdues étaient légèrement plus grosses que celles qui ont été capturées par le chalut. Les prises ramenées par le cul-de-chalut à mailles carrées comportaient en moyenne 121 crevettes au kilo, comparativement à une moyenne de 130 crevettes au kilo dans le cas des prises capturées au moyen d'un cul-de-chalut à mailles en losange de 43 mm.

INTRODUCTION

The northern shrimp fishery, which began in the mid-1970's, is conducted in NAFO Divisions 0, 2, and Subdivision 3K. Currently, 17 Canadian licence holders use 50 to 70 meter ice-strengthened vessels in the fishery year-round. The season begins off the northeast coast of Newfoundland in January where vessels can operate relatively free of harsh ice conditions in the winter months. During the spring and summer months, as ice conditions improve, the fleet moves north off Labrador and up the Davis and Hudson Straits. The season usually closes off Labrador in the fall.

While over 30 species of shrimp commonly occur in eastern Canadian waters, only *Pandalus borealis* and *Pandalus montagui* are harvested commercially. The former is, by far, the most sought after. Both species are generally referred to as northern shrimp, but are also known as pink shrimp and striped shrimp, respectively (MacDonald et al., 1990).

Freezer trawlers harvest in excess of 25,000 MT of shrimp annually from the northern shrimp fishery. While this fishery is economically valuable, the by-catch of approximately 5,000 MT of non-targeted species (cod, plaice, redfish, turbot, etc.) is a major concern and one which has been difficult to resolve. The recent decline in many commercial fish stocks, especially northern cod, has increased the need to develop more selective shrimp fishing gear.

Efforts to make shrimp trawls species selective have been pursued since the beginning of this fishery. Several methods which relied on net panels to separate shrimp from other species were developed and have performed successfully in experimental trials (Way, 1977; Karlsen and Larsen, 1988; Averill, 1988). However, attempts to introduce these methods commercially were generally unsuccesful due to their complicated design and lack of adaptability. The Nordmore grate (Isaksen, 1990) was the first system to effectively combine a high percentage of by-catch reduction with low shrimp loss under commercial conditions. In addition, with the main component of this system being a rigid grate, it is less affected by water flow and obstructions than designs using net panels. This system has been globally tested and is presently compulsory for shrimp trawling in several countries (Valdemarsen, 1993).

Between January and March of 1993, the Department of Fisheries and Oceans (DFO), in conjunction with Fishery Products International (FPI), performed a study in NAFO Subdivisions 2J and 3K (Figure 1) aimed at reducing by-catch in the northern shrimp fishery. The primary objective of this study was to investigate the effectiveness of three Nordmore grates (bar spacings of 22, 25, and 28mm) in reducing this by-catch. A secondary objective was to investigate the capability of a square mesh codend to reduce the catch of small (industrial) shrimp.

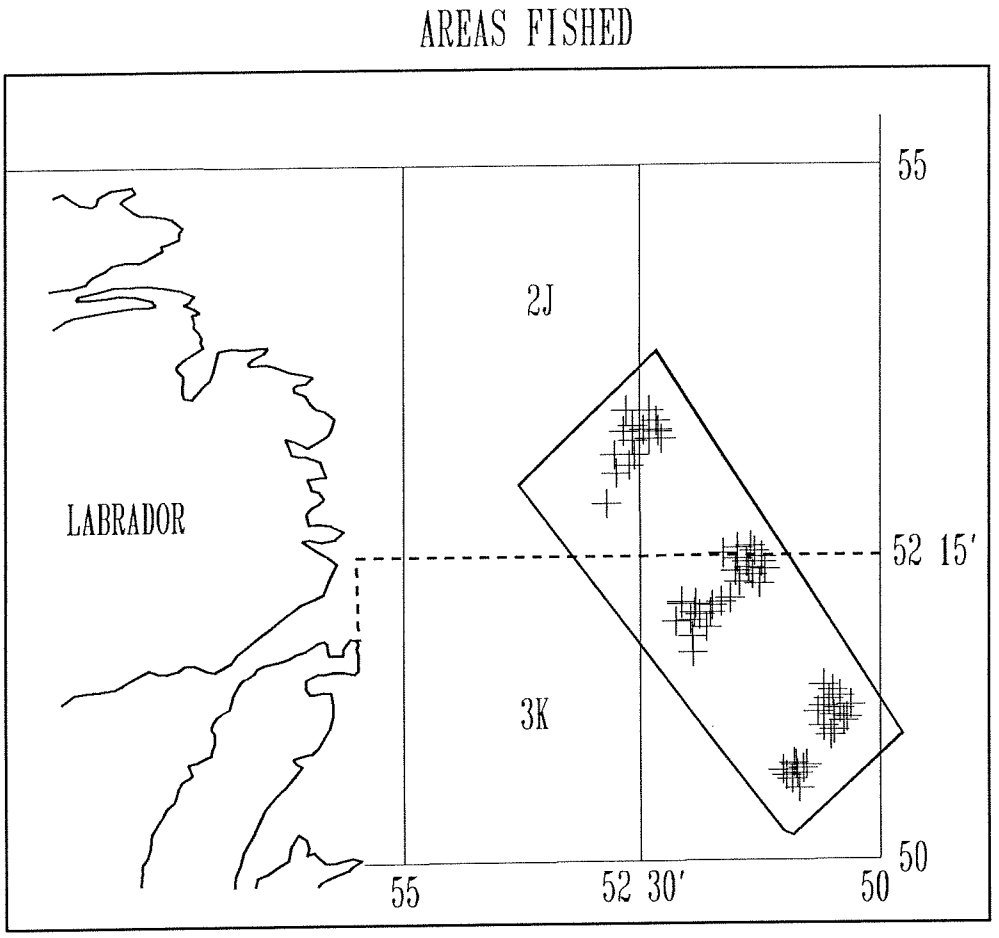


Figure 1: Study area for the Nordmore grate comparisons and the square mesh assessment.

MATERIALS AND METHODS

All experiments for this study were conducted during a 54 day cruise on the M/V "Newfoundland Otter", a 60 meter shrimp vessel owned and operated by Fishery Products International (FPI). In total, 216 sets were made in water depths ranging from 286 to 507 meters. Fifty-two successful sets were made using the experimental trawl with Nordmore grates installed (Figure 2). Set duration, which depended on the density of shrimp and bottom conditions, ranged from 18 minutes to 5 hours. Experimental fishing was conducted for a total of 35 days and this included days when the commercial trawl was being used (i.e. no Nordmore grate) to provide a catch comparison.

Two ANGMAGSSALIK 3600 x 40mm mesh shrimp trawls (Figure 3) were constructed identically. The trawl had a footrope length of 72 meters and a headrope length of 63 meters. The footrope contained 46 steel rollers, each 53cm in diameter, and the headrope had 678 plastic floats, each 20cm in diameter. The mesh sizes in the trawl were: wings 155mm; square and bellies 60mm; lengthening piece and twin codends 43mm. The trawl doors were "perfect oval" and measured 13 square meters with each weighing 3900 kg. This gear is commonly used in the commercial shrimp fishery.

Three stainless steel Nordmore grates (Figure 2) with bar spacings of 22, 25, or 28mm were used. Each Nordmore grate sorting system consisted of a rectangular frame measuring 1.3 x 1.5 meters, a 38mm mesh guiding funnel and a fish release opening. Eight floats were attached along the top of

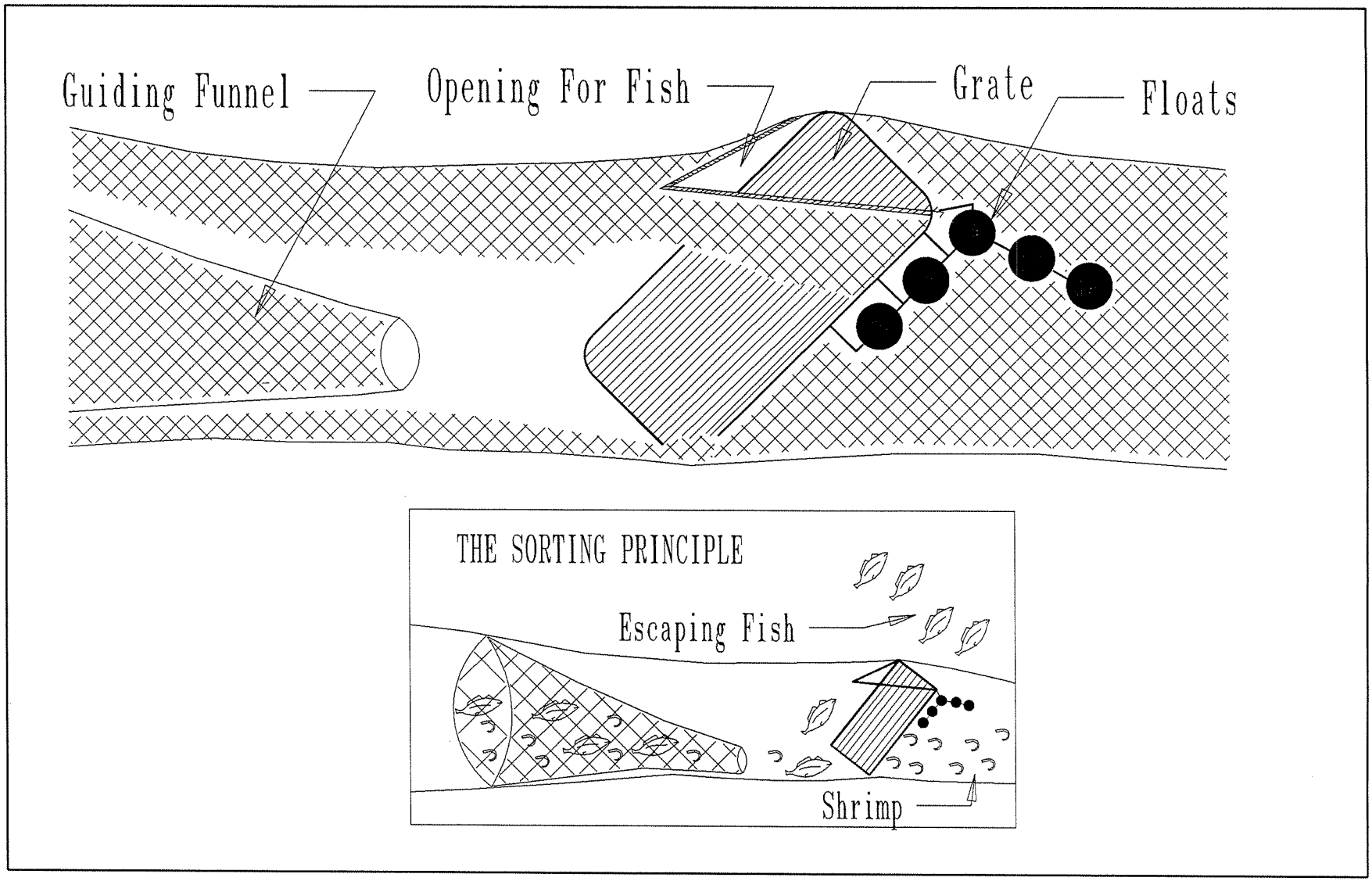


Figure 2: The Nordmore Grate: its setup and operation.

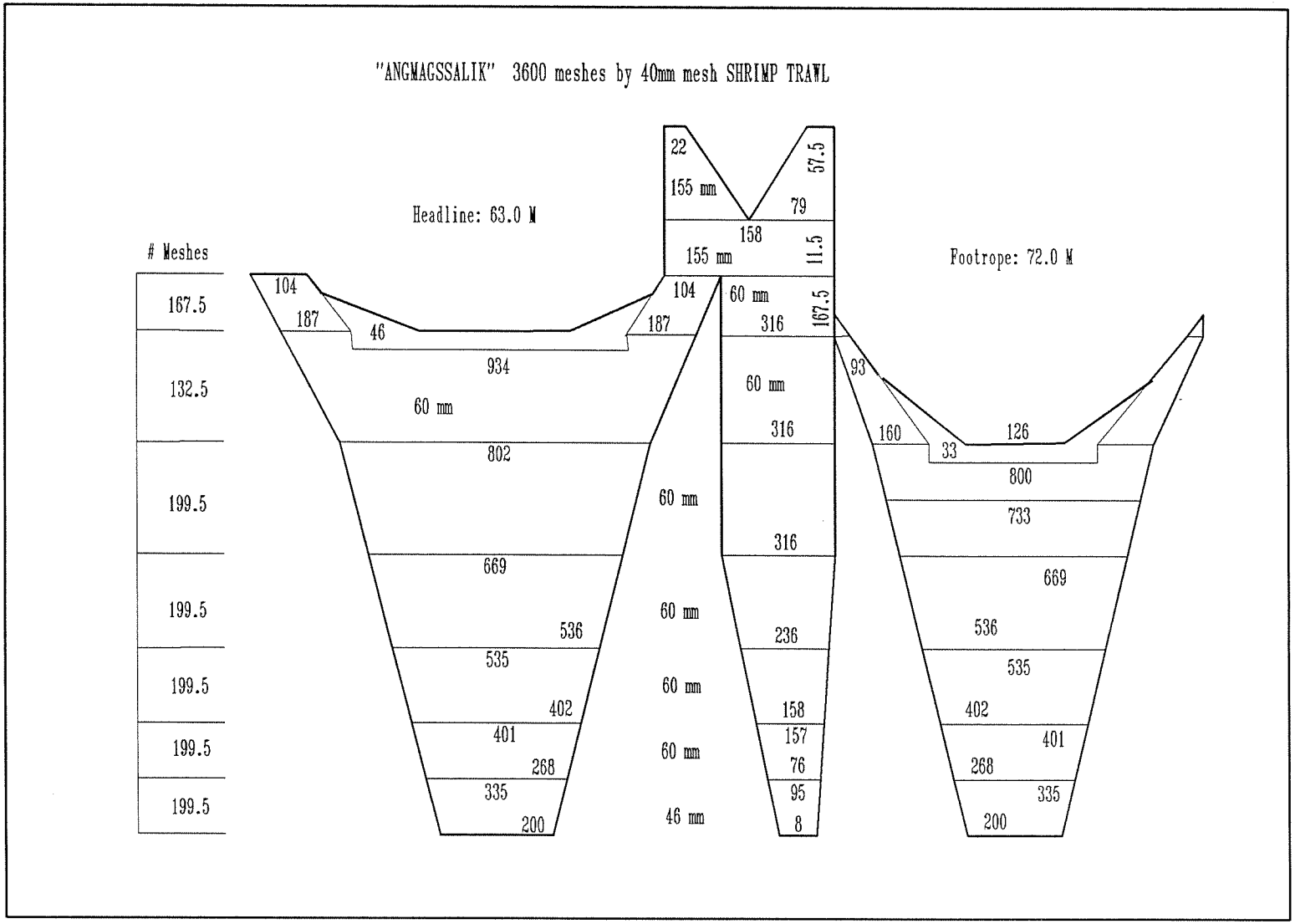


Figure 3: Schematic diagram of the Angmagssalik shrimp trawl.

the grate and five floats were attached to each side in order to neutralize its weight in the water. Each Nordmore grate system was installed in a section of the lengthening piece for fast installation and removal from the trawl. All three grates were installed at a nominal angle of 48°.

The diamond mesh codend was constructed from 43mm double nylon mesh and the square mesh from 43mm mesh single polyethylene netting. The retainer bag used with the 22mm Nordmore grate experiment was constructed from 45mm diamond single polyethylene mesh.

During the cruise, five different experiments were performed:

1. 22mm Nordmore grate
2. 25mm Nordmore grate
3. 28mm Nordmore grate
4. 43mm square mesh
5. 22mm Nordmore grate with retainer bag.

The first four experiments were carried out using a variation of the alternate haul method. Using this method, the experimental trawl was operated for 24 consecutive hours with an experimental device installed and this was followed by 24 consecutive hours fishing with the commercial trawl. During the fifth experiment, the experimental trawl was used with a retainer bag over the Nordmore grate to catch escaping fish. This method, an application of the covered codend procedure, was only used for the 22mm grate system.

A Scanmar net monitoring system was used to measure door spreads and headline heights, while a combined speed and angle sensor mounted on the aft

side of the grate provided readings of water flow and grate angle. Support ropes were attached at the top corners of the grate and down to the lastridge ropes to prevent the grate angle from decreasing as the catch accumulated in the codend.

During the cruise, the vessel carried four DFO representatives who collected data and monitored fishing operations on a 24-hour basis. The crew repaired and maintained both trawls, installed and removed Nordmore grate systems and codends, and assisted with sampling the catch.

After each set was completed, the catch was separated by species, placed in baskets and total weights recorded. Random samples were taken from each of the main species which included shrimp, cod (*Gadus morhua*), turbot (*Reinhardtius hippoglossoides*), redfish (*Sebastes fasciatus*) and American plaice (*Hippoglossoides platessoides*). The shrimp samples contained 250 to 300 individuals and their carapace lengths were recorded in 0.5mm groupings, while fish samples of 150 to 450 individuals were taken from each of the main by-catch species and their fork lengths were recorded in 1cm groupings.

During the alternate haul experiments total catch weights, individual fish lengths and fishing effort were compared for the commercial and experimental trawl. Selectivity curves were generated for the exclusion probabilities of cod, plaice, turbot and redfish when using the 22mm Nordmore grate. This was implemented with a maximum likelihood logistic regression procedure and was only performed for the study using the retainer bag over the grate.

The length of shrimp in the codend of each experimental trawl which used a Nordmore grate was compared with the length found in the codend of the commercial trawl for all sets using a nested ANOVA comparison test. In addition, the length of shrimp captured when using the three different grates was compared using a similar nested ANOVA comparison test. These tests were performed to make the appropriate comparisons and control for differences that may be associated with different days and/or areas fished.

The study with the 22mm grate used a codend of 43mm diamond mesh and a retainer bag made from 45mm diamond mesh placed over the grate to capture the shrimp lost with grate usage. The shrimp loss to be assessed may be biased by the unequal mesh sizes. If the mean length of shrimp is larger in the retainer bag as opposed to the codend, this would indicate that the larger mesh size of the retainer was releasing more small shrimp than was the codend and/or the Nordmore grate was excluding larger shrimp. A two-factor ANOVA comparison test was used to determine whether the mean shrimp length differed between the retainer and codend for all sets.

Length frequency distributions were produced for each comparison (Figures 4-8). In generating these distributions, a more continuous representation was produced by averaging the count of shrimp in each length group with the count in the two previous and the two following length groups.

RESULTS

A variation of the alternate haul method was employed to assess the three Nordmore grates and the 43mm square mesh codend. As previously described, fishing was carried out with the experimental trawl for 24 hours and was followed by 24 hours fishing with the commercial trawl. A high variability in catches, which is common in shrimp fishing, and delays for catch processing made it difficult to carry out these comparisons. The amount of time fished on any one day was unlikely to match that of a preceding or following day. This resulted in shrimp catch rates varying from set to set; the largest catch of 20 tons resulted from only a two hour tow. This prompted the use of a retainer bag over the 22mm Nordmore grate in one experiment to confirm the results that were obtained from the alternate hauls.

The first two days of the trip were devoted to establishing trawl parameters and comparing catches for two ANGMAGSSALIK, 3600 trawls. Ten sets demonstrated that both trawls were performing similarly; the trawl headline height ranged from 8.8 to 9.5 meters and door spread ranged from 64 to 68 meters for all sets. These readings were obtained using Scanmar height and spread sensors. Catch rates of shrimp and by-catch species were also found to be similar between sets.

Water flow ranged from 0 knots (indication of blockage) to 1.7 knots. Grate angle readings were usually 48° but ranged from 48° to 20°. The grate

angle decrease was attributable to the attachment of a retainer over the grate in conjunction with fishing dense shrimp concentrations. When the retainer bag was being used angle readings showed a decrease, while water flow readings were found to be similar to those obtained with the direct comparisons which did not use a retainer.

Before fishing trials commenced, experimental gear was checked to ensure compliance with cruise plan specifications. Measurements of bar spacings for all three Nordmore grates showed a deviation from the nominal spacing by +/- 2mm. All other gear parameters were as specified.

EXPERIMENT #1 - 22mm GRATE

Catch and effort comparisons were made between the experimental trawls with the 22mm Nordmore grate and the commercial trawls (Table 1). Sixteen sets with each trawl showed the experimental trawl catching less of all species than the commercial trawl. The difference (less) in catch per hour for the trawl with the grate was: 95.2% for cod, 88.3% for plaice, 69.7% for turbot, 59.8% for redfish and 82.7% for other by-catch species. The total by-catch from the experimental trawls was 1,005 kg or 2.2% of the total catch and from the commercial trawls it was 3,478 kg or 7%, respectively.

When the grate was used, the shrimp catch rate ranged from 470 to 2,160 kg/hour and from 454 to 3676 kg/hour when the commercial tawl (i.e.

no grate) was used. The total catch of shrimp from the experimental trawls was 43,975 kg in 41.5 hours of fishing time, while it was 46,289 kg from 33 hours of fishing with the commercial trawl. This represented a 24.4% difference (less) in shrimp catch per hour when the 22mm Nordmore grate was used. The shrimp length distribution caught did not differ significantly between the experimental and commercial trawls (Figure 4) ($F = 0.938$, $p = 0.3643$). The average number of shrimp/kg for the experimental trawl was 120.7, while it was 128.6 for the commercial trawl (Table 2). This would indicate that larger shrimp were caught in the experimental trawl as compared to the commercial trawl. However, this tendency is reversed for the other grate bar spacings tested. Therefore the result may depend on whether the size of shrimp in the population being fished differs significantly between the experimental and commercial sets.

TABLE 1: Comparison of Catch Between Shrimp Trawl with a 22mm Nordmore Grate and a Shrimp Trawl without a Nordmore Grate

Date: From January 18 to January 24, 1993

	With Grate	Without Grate	Difference (less) %
Number of Sets	16	16	-
Duration (Hours)	41.5	33	-
Shrimp (kg)	43,975	46,289	-
Shrimp (C.P.H.)	1,060	1,403	24.4
Turbot (kg)	409	1,078	-
Turbot (C.P.H.)	9.9	32.7	69.7
American Plaice (kg)	28	198	-
American Plaice (C.P.H.)	0.7	6	88.3
Cod (kg)	27	486	-
Cod (C.P.H.)	0.7	14.7	95.2
Redfish (kg)	291	574	-
Redfish (C.P.H.)	7	17.4	59.8
Other By-Catch (kg)*	250	1,142	-
Other By-Catch (C.P.H.)	6	34.6	82.7
Total By-Catch (kg)	1,005	3,478	-
% By-Catch is of Total Catch	2.2	7	-

*Other By-Catch species include: skate, sculpin, lantern fish, eelpout, wolffish.

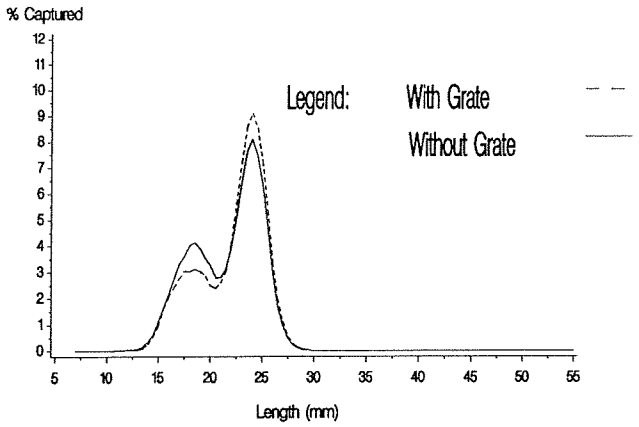


Figure 4: Shrimp length comparisons: percent captured with and without a 22 mm grate.

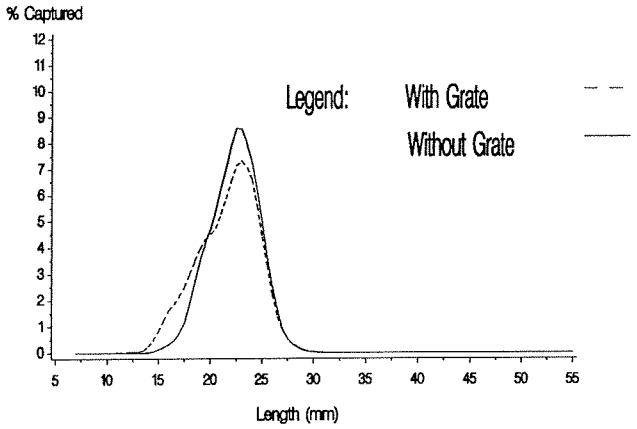


Figure 5: Shrimp length comparisons: percent captured with and without a 25 mm grate.

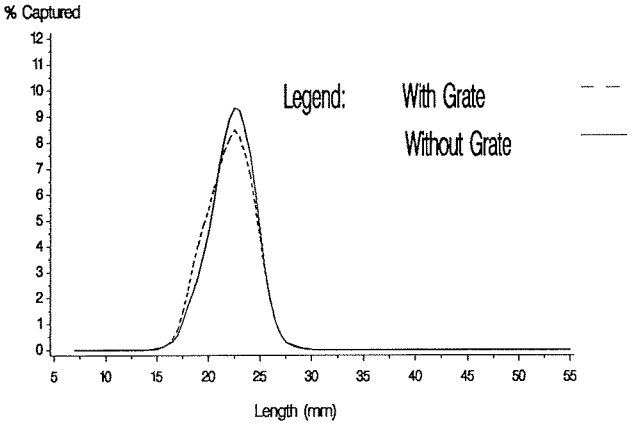


Figure 6: Shrimp length comparisons: percent captured with and without a 28 mm grate.

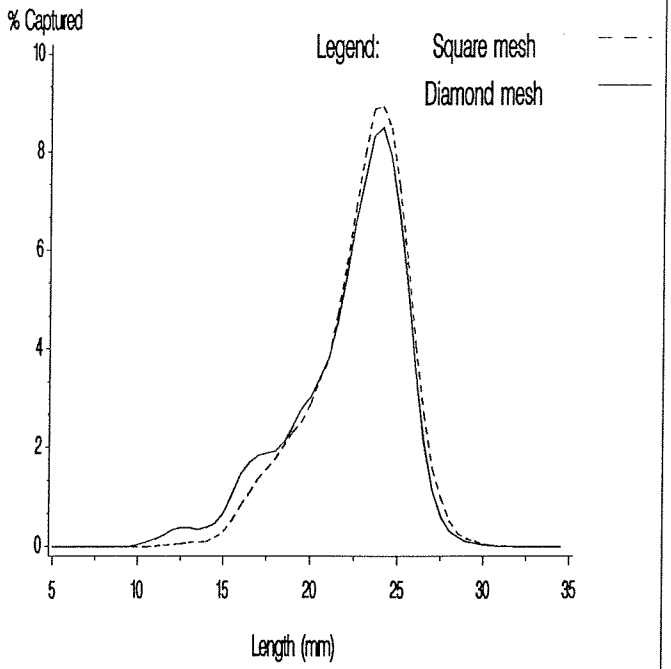


Figure 7: Shrimp length comparisons: percent captured using a 43mm square mesh and 43mm diamond mesh.

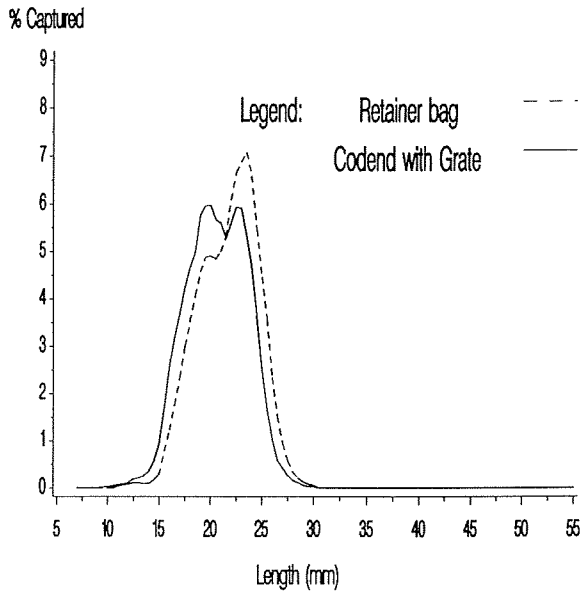


Figure 8: Shrimp length comparisons: percent captured using a codend with a 22 mm grate and retainer bag.

TABLE 2: Shrimp size captured in a trawl with a Nordmore grate of 22mm bar spacing compared to a trawl without a grate.

Set Number	With Grate (#/kg)	Set Number	Without Grate (#/kg)
11	123.1	17	138.5
12	111.5	18	120.5
13	126.2	19	116.5
15	120.8	20	135.0
16	125.2	21	132.0
23	96.2	22	105.6
24	93.5	28	111.5
25	110.8	31	128.6
26	108.1	32	110.0
27	108.1	33	165.6
30	126.8	38	145.0
40	159.5	39	129.6
41	140.5	45	125.9
42	132.0	46	136.5
43	130.4		
44	117.9		
Average	120.7	Average	128.6

EXPERIMENT #2 - 25mm GRATE

In comparing the experimental trawls using the 25mm Nordmore grate and the commercial trawls (Table 3), the fifteen sets with each showed the experimental trawl catching less of all species. The difference (less) in catch per hour for the trawl with the grate was 99.6% for cod, 86.7% for plaice, 63.8% for turbot, 82.4% for redfish and 78% for other by-catch species. The total by-catch from the experimental trawls was 860 kg or 2.1% of the total catch and from the commercial trawls it was 3,658 kg or 6.9%, respectively.

The shrimp catch rate ranged from 366 to 1,829 kg/hour when the grate was used and from 351 to 10,347 kg/hour when the commercial trawl was employed. The total catch of shrimp from the experimental trawls was 35,511 kg in 43.6 hours of fishing time, while it was 49,045 kg from 34 hours of fishing with the commercial trawl. The result was a 43.6% difference (less) in shrimp catch per hour when the Nordmore grate was used. The shrimp length distribution did not differ significantly between the experimental trawl and the commercial trawl (Figure 5) ($F = 1.1214$, $p = 0.2934$). The average number of shrimp/kg for the experimental trawl was 126.5, while it was 116.5 for the commercial trawl (Table 4).

TABLE 3: Comparison of Catch Between Shrimp Trawl with a 25mm Nordmore Grate and a Shrimp Trawl without a Nordmore Grate

Date: From January 25 to February 6, 1993

	With Grate	Without Grate	Difference (Less)%
Number of Sets	15	15	-
Duration (Hours)	43.6	34	-
Shrimp (kg)	35,511	49,045	-
Shrimp (C.P.H.)	814	1,443	43.6
Turbot (kg)	310	667	-
Turbot (C.P.H.)	7.1	19.6	63.8
American Plaice (kg)	45	256	-
American Plaice (C.P.H.)	1	7.5	86.7
Cod (kg)	16	785	-
Cod (C.P.H.)	0.1	23.1	99.6
Redfish (kg)	243	1,085	-
Redfish (C.P.H.)	5.6	31.9	82.4
Other By-Catch (kg)*	246	865	-
Other By-Catch (C.P.H.)	5.6	25.4	78
Total By-Catch (kg)	860	3,658	-
% By-Catch is of Total Catch	2.1	6.9	-

*Other By-Catch species include: skate, shark, grenadier, eelpout, witch.

TABLE 4: Shrimp size captured in a trawl with a Nordmore grate of 25mm bar spacing compared to a trawl without a grate.

Set Number	With Grate (#/kg)	Set Number	Without Grate (#/kg)
50	117.2	52	127.9
51	150.0	53	127.7
55	144.3	61	119.2
56	113.9	62	118.8
57	127.3	63	112.4
58	118.6	64	111.2
59	121.4	65	115.4
66	120.4	75	115.4
68	129.6	76	112.4
70	113.6	77	103.7
71	130.0	78	113.6
72	174.3	79	121.7
82	109.2	80	109.1
83	112.7	86	121.8
85	115.8		
Average	126.5	Average	116.5

EXPERIMENT #3 - 28mm GRATE

In comparing nine sets using the experimental trawl with a 28mm grate and the eight sets using the commercial trawl (Table 5), it was found that the experimental trawl caught less of all species. The difference (less) in catch per hour for the trawl with the grate was 98.1% for cod, 83.3% for plaice, 72.1% for turbot, 81.5% for redfish and 81.7% for other by-catch species. The total by-catch from the experimental trawls was 348 kg or 1% of the total catch and from the commercial trawl it was 1,728 kg or 5.8%, respectively.

When the grate was used, the shrimp catch rate ranged from 552 to 1,492 kg/hour and from 56 to 3,710 kg/hour when the commercial trawl was used. The total catch of shrimp from the experimental trawls was 33,087 kg in 31.1 hours of fishing time, while it was 27,942 kg from 25.5 hours of fishing with the commercial trawl. This represents a 2.9% difference (less) in shrimp catch per hour when the Nordmore grate was used. The shrimp length distributions did not differ significantly between the experimental and commercial trawls (Figure 6) ($F = 1.088$, $p = 0.3468$). The average number of shrimp/kg for the experimental trawl was 129.9, while it was 122.3 for the commercial trawl (Table 6).

TABLE 5: Comparison of Catch Between Shrimp Trawl with a 28mm Nordmore Grate and a Shrimp Trawl without a Nordmore Grate

Date: From February 7 to February 15, 1993

	With Grate	Without Grate	Difference (Less)%
Number of Sets	9	8	-
Duration (Hours)	31.1	25.5	-
Shrimp (kg)	33,087	27,942	-
Shrimp (C.P.H.)	1,064	1,096	2.9
Turbot (kg)	89	266	-
Turbot (C.P.H.)	2.9	10.4	72.1
American Plaice (kg)	11	62	-
American Plaice (C.P.H.)	0.4	2.4	83.3
Cod (kg)	6	317	-
Cod (C.P.H.)	0.2	12.4	98.1
Redfish (kg)	114	511	-
Redfish (C.P.H.)	3.7	20	81.5
Other By-Catch (kg)*	128	57	-
Other By-Catch (C.P.H.)	4.1	22.4	81.7
Total By-Catch (kg)	348	1,728	-
% By-Catch is of Total Catch	1	5.8	-

*Other By-Catch species include: skate, shark, eelpout, wolffish.

TABLE 6: Shrimp size captured in a trawl with a Nordmore grate of 28mm bar spacing compared to a trawl without a grate.

Set Number	With Grate (#/kg)	Set Number	Without Grate (#/kg)
94	129.5	89	113.3
95	120.9	90	117.3
96	130.0	91	128.8
97	130.0	92	126.5
98	130.0	100	127.1
102	130.4	103	132.1
105	127.0	104	120.4
106	137.5	111	113.0
112	134.1		
Average	129.9	Average	122.3

EXPERIMENTS #1-3 - COMPARISON OF BAR SPACINGS

The mean length of shrimp caught when using Nordmore grates of 22, 25 or 28 mm bar spacings was 22.07, 22.04 and 22.26 mm, respectively. There was no significant difference between the mean lengths caught using the grates ($F = 0.118$, $p = 0.8896$). The magnitude of the difference in shrimp/kg between the experimental and commercial trawls differed very little between grate sizes used, however, it was lowest for the 28mm grate (7.6 shrimp/kg), followed by the 22mm grate (7.9 shrimp/kg) and 25mm grate (10.0 shrimp/kg). Moreover, the difference in the shrimp catch per hour between the experimental and commercial trawls was also found to be lowest for the 28mm grate and again followed by the 22mm grate and then the 25mm grate.

EXPERIMENT #4 - SQUARE MESH CODEND

Comparisons between the 43mm square and the 43mm diamond mesh codends (Table 7) resulted in eleven and nineteen sets, respectively. The shrimp catch rate ranged from 268 to 1,390 kg/hour when using square mesh and from 319 to 5,362 kg/hour for diamond mesh. The total catch of shrimp from the trawls with the square mesh codend was 31,066 kg in 43.2 hours (i.e. 719 kg/hour) of fishing time and 77,803 kgs in 54.7 hours (i.e. 1,422 kg/hour) of fishing with the diamond mesh codend. The shrimp length distribution varied slightly between the 43mm square mesh codend and the

TABLE 7: Comparison of Catch Between Shrimp Trawl with a 43mm Square Mesh Codend, and a Shrimp Trawl with a 43mm Diamond Mesh Codend

Date: From February 16 to February 23, 1993

	Square Mesh Codend	Diamond Mesh Codend
Number of Sets	11	19
Duration (Hours)	43.2	54.7
Shrimp (kg)	31,066	77,803
Shrimp (C.P.H.)	719	1,422
Turbot (kg)	388	1,542
Turbot (C.P.H.)	9	28.2
American Plaice (kg)	192	347
American Plaice (C.P.H.)	4.4	6.3
Cod (kg)	1,058	2,119
Cod (C.P.H.)	24.5	38.7
Redfish (kg)	764	1,021
Redfish (C.P.H.)	17.7	18.7
Other By-Catch (kg)*	473	697
Other By-Catch (C.P.H.)	10.9	12.7
Total By-Catch (kg)	2,875	5,726
% By-Catch is of Total Catch	8.5	6.9

*Other By-Catch species include: skate, capelin, wolffish, eelpout, grenadier.

43mm diamond mesh codend (Figure 7) ($F = 3.971$, $p = 0.0226$). The mean length over the three areas tested was 22.90mm for the square mesh and 22.31mm for the diamond mesh. However in the three areas where this comparison was made, the difference in the mean shrimp length exceeded 1mm only in the area where small shrimp predominated. The average number of shrimp/kg for the square mesh codend was 120.9 and for the diamond mesh codend it was 129.8 (Table 8).

TABLE 8: Shrimp size captured in a trawl with 43mm diamond mesh compared to shrimp size captured with 43mm square mesh.

Set Number	Diamond Mesh (#/kg)	Set Number	Square Mesh (#/kg)
124	92.9	119	106.4
113	111.7	120	108.3
114	115.8	122	102.5
115	103.8	132	119.0
116	116.5	133	120.0
117	106.4	134	107.2
118	102.9	135	115.8
121	104.6	136	123.6
126	114.3	169	158.6
127	125.5	170	147.9
130	120.0		
131	117.3		
173	176.9		
174	205.7		
177	171.0		
178	192.1		
Average	129.8	Average	120.9

EXPERIMENT # 5 - RETAINER BAG

This experiment used a retainer bag installed over the 22m Nordmore grate to catch fish excluded by the grate. In 11 successful sets, 36,986 kg of shrimp were caught, 7,182 kg in the retainer bag and 29,804 kg in the codend. This represented a combined shrimp loss (catch in the retainer bag) of 19.4% (Table 9). The loss for individual sets ranged from 0.3% to 41.8% with the heaviest losses coinciding with dense concentrations of shrimp as was indicated by echo sounder readings. Use of the retainer bag over the Nordmore grate caused the grid angle to decrease during tows and this change was most pronounced when trawling through heavy shrimp concentrations. This decrease in grid angle would have caused less of the grate's surface area to be exposed to the catch and would explain the high shrimp losses for some sets.

It was found that 97% of the cod, 82% of the plaice, 69% of the redfish, and 72% of the turbot were guided out of the trawl by the grate. The by-catch amounted to 4% (i.e. 1,562kg) of the total catch with only 11% (i.e. 172kg) of this by-catch being from the codend, the remaining 1,390kg was caught in the retainer. These percentages are similar to those obtained during the alternate haul experiments. The shrimp length distribution differed significantly between the codend and the retainer bag (Figure 8) ($F=8.997$, $p=0.0133$). The average number of shrimp/kg for the retainer was 136.3, while it was 154.9 for the codend (Table 10). There appeared to be a slight difference in

TABLE 9: Catch Results for the Codend and Retainer Over the 22mm Nordmore Grate

Date: From February 23 to March 6, 1993

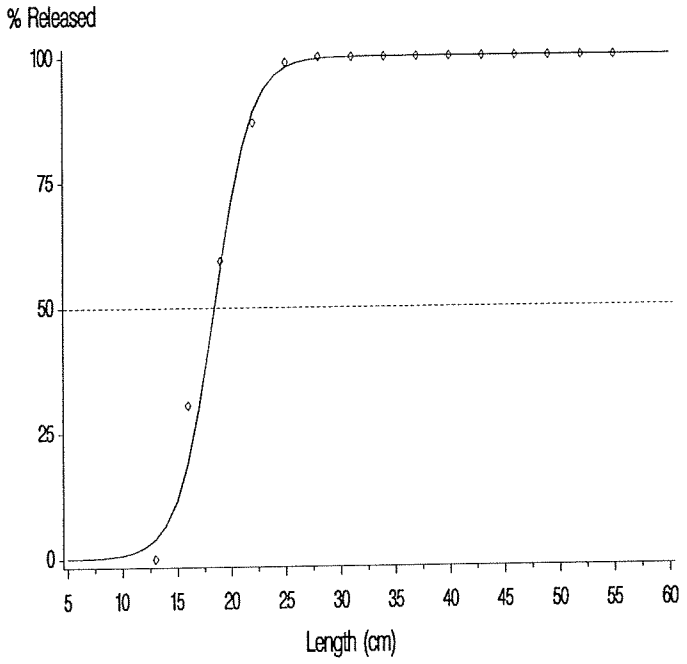
Number of Sets = 11 **Duration (Hours) = 30.8**

	Retainer	Codend	% Reduction in Catch
Shrimp (kg)	7,182	29,804	19.4
Turbot (kg)	194	71	73.3
American Plaice (kg)	97	21	82.2
Cod (kg)	970	25	97.5
Redfish (kg)	129	55	70.0
Total By-Catch (kg)	1,390	172	89

shrimp mean length between the codend and retainer; 20.59mm and 21.68mm, respectively. This is different from what was found with the alternate haul experiments (i.e. same mean length in experimental and commercial tow) and is possibly due to a slightly larger mesh size in the retainer bag (45mm vs. 43mm). Masking of the codend meshes by the retainer bag and by the codend cover (140mm) may have also contributed to this difference. Therefore, the shrimp loss estimates may be slightly low.

The retainer bag experiment provided sufficient data to develop selectivity curves for the four main by-catch species. The 50% retention lengths for the 22mm Nordmore grate are as follows: cod 18.45cm; turbot 19.80cm; redfish 14.42cm; and plaice 15.88cm (Figures 9, 11, 13, and 15). The selectivity curves showed narrow selection ranges for round fish; cod 3.71cm and redfish 3.11cm, while the selection range was higher for flatfish; plaice 9.52cm and turbot 7.81cm (Figure 17).

Cod over 22cm (Figure 10), plaice over 26cm (Figure 12), turbot over 26cm (Figure 14) and redfish over 18 cm (Figure 16) were all released by the 22mm grate. Very small fish of all species (e.g. small cod and capelin) were not effectively released by the grate.



Fitted model results :

Model Parameters:
a −10.9044 (0.6536)
b 0.5909 (0.0316)

Model Goodness of Fit:
deviance 15.86
d.f. 13
prob. 0.256

L25 16.60
L50 18.45
L75 20.31
S.R. 3.71

Figure 9: Cod selectivity curve and observed values for a shrimp trawl using a 22 mm Nordmore grate and retainer bag.

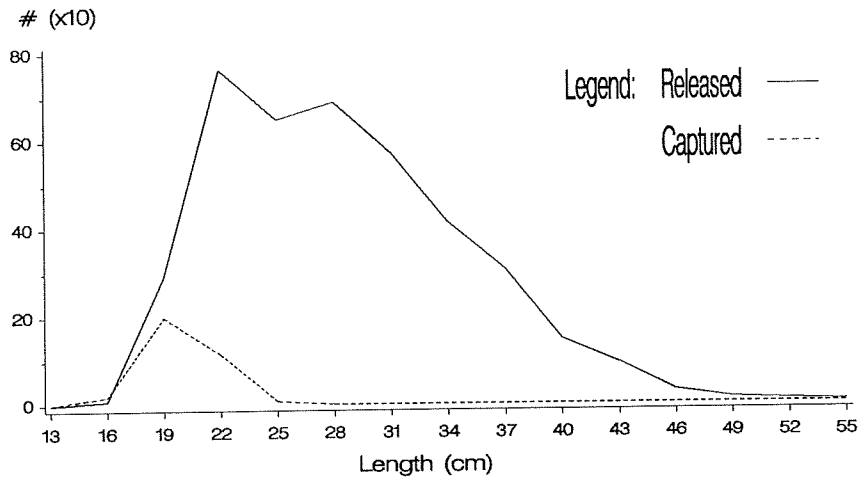
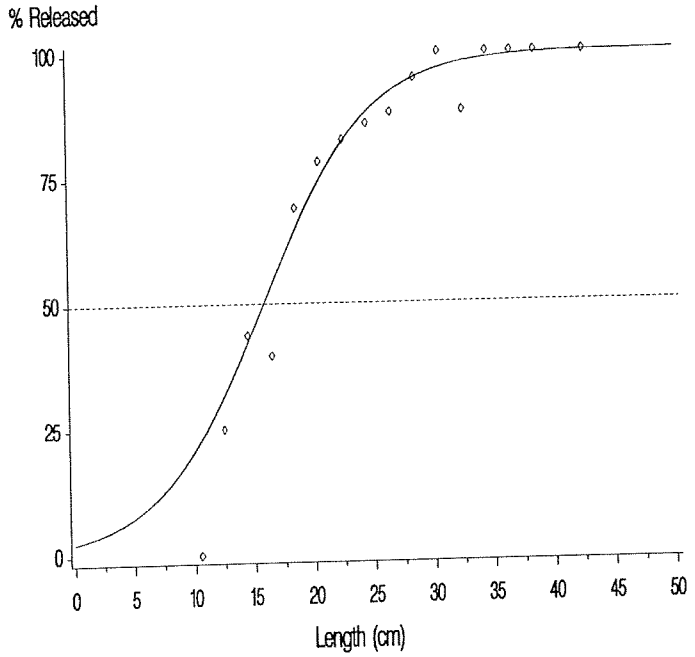


Figure 10: Cod length frequency distribution for a shrimp trawl using a 22 mm grate and a retainer bag.



Fitted model results :

Model Parameters:

a	−3.6668 (0.4429)
b	0.2309 (0.0216)

Model Goodness of Fit:

deviance	19.67
d.f.	14
prob.	0.141

L25	11.12
L50	15.88
L75	20.64
S.R.	9.52

Figure 11: Plaice selectivity curve and observed values for a shrimp trawl using a 22 mm Nordmore grate and retainer bag.

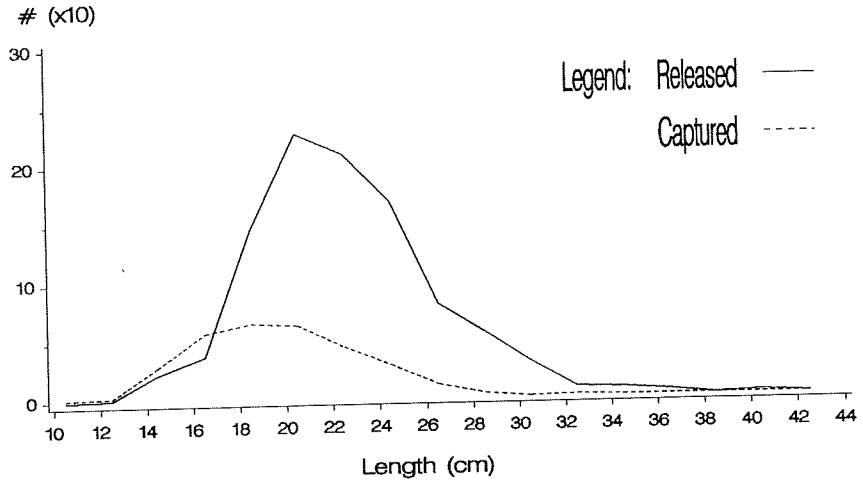
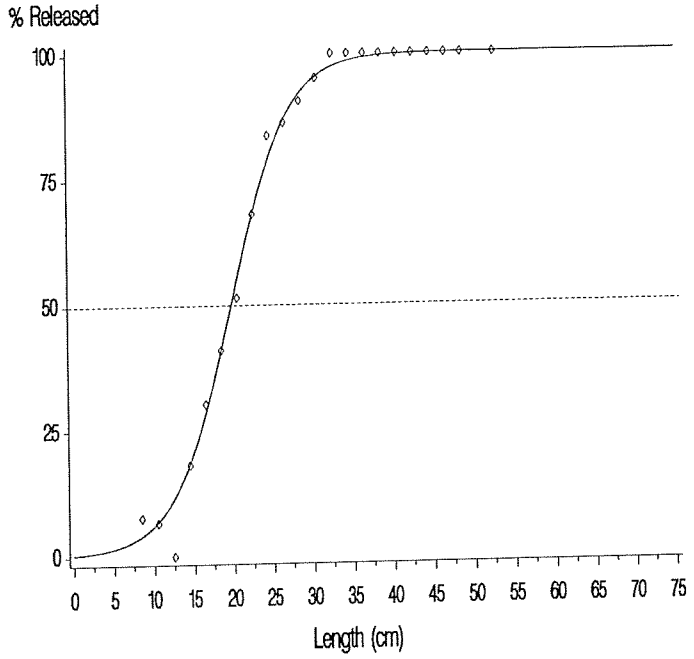


Figure 12: Plaice length frequency distribution for a shrimp trawl using a 22 mm grate and a retainer bag.



Fitted model results :

Model Parameters:

a	−5.5680 (0.2753)
b	0.2812 (0.0141)

Model Goodness of Fit:

deviance	12.35
d.f.	20
prob.	0.904

L25	15.89
L50	19.80
L75	23.71
S.R.	7.81

Figure 13: Turbot selectivity curve and observed values for a shrimp trawl using a 22 mm Nordmore grate and retainer bag.

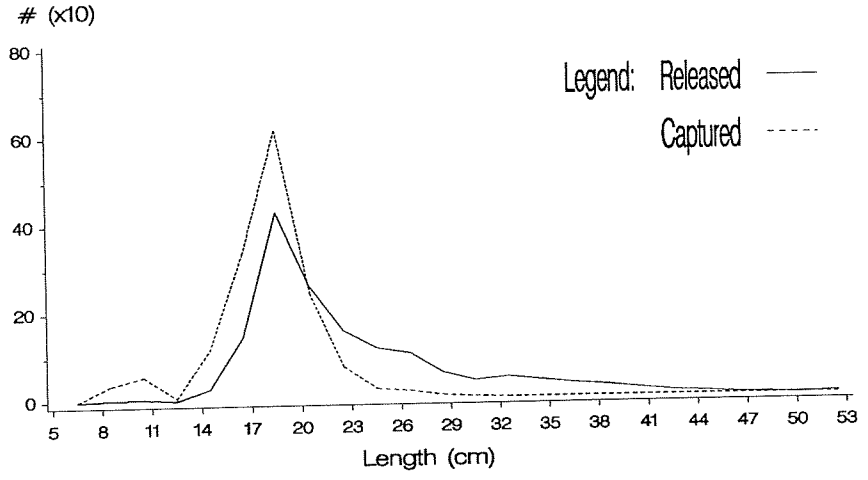
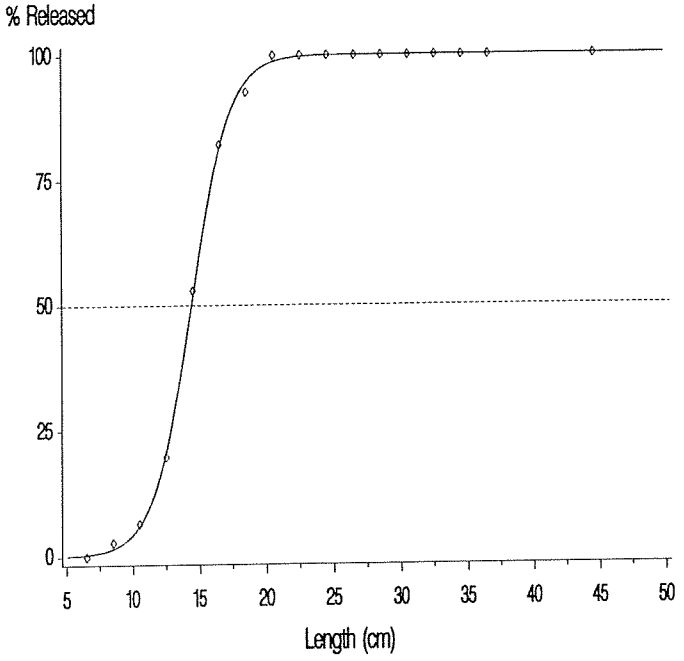


Figure 14: Turbot length frequency distribution for a shrimp trawl using a 22 mm grate and a retainer bag.



Fitted model results :

Model Parameters:

a −10.1649 (0.3252)

b 0.7051 (0.0237)

Model Goodness of Fit:

deviance 7.26

d.f. 15

prob. 0.950

L25 12.86

L50 14.42

L75 15.97

S.R. 3.11

Figure 15: Redfish selectivity curve and observed values for a shrimp trawl using a 22 mm Nordmore grate and retainer bag.

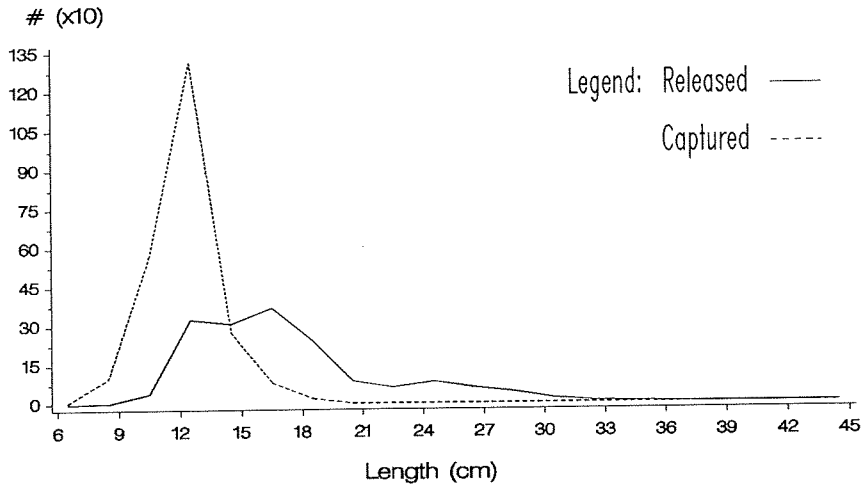


Figure 16: Redfish length frequency distribution for a shrimp trawl using a 22 mm grate and a retainer bag.

TABLE 10: Shrimp size captured in a trawl using a Nordmore grate of 22mm bar spacing compared to the size captured in an attached retainer bag.

Set Number	Codend (#/kg)	Retainer Bag (#/kg)
152	169.5	156.3
154	129.0	132.5
155	150.5	159.5
158	228.2	186.2
159	119.1	102.6
160	143.2	103.3
168	173.6	113.8
171	177.2	172.9
203	141.6	112.2
204	134.1	117.8
207	138.1	142.0
Average	154.9	136.3

DISCUSSION

The results from the alternate haul and retainer bag experiments indicate a huge reduction in the by-catch of all species with the use of Nordmore grates having bar spacings of 22mm , 25mm or 28mm. Usage of either grate was shown not to significantly reduce the mean shrimp carapace length caught as compared to that of a commercial trawl (Figures 4 - 6). There also appears to be no difference in the shrimp mean length caught with an increase in grate bar spacing; 22mm, 25mm or 28mm.

The findings of a similar mean shrimp length caught while using either Nordmore grate as opposed to a commercial trawl were comparable to what was found in Norway (Isaksen et al. 1990) and the Scotia-Fundy region (Cooper and Hickey, 1991). However, the heavy shrimp losses (up to 41%) that were encountered for several sets during the retainer bag experiment (22mm grate) of this study contrasted dramatically with losses of less than 5% that were found in Norway (Isaksen et al., 1990) and less than 10% reported for the Scotia-Fundy region (Cooper and Hickey, 1991) when a 19mm Nordmore grate was used. As a partial explanation, it was noticed that the heavy losses encountered in this study coincided with sets when the grate angle decreased substantially from its installed value of 48° as well as when echo soundings indicated dense shrimp concentrations. This would indicate that the grate angle

tends to decrease when fishing in dense shrimp concentrations with a retainer bag over the grate.

The shrimp losses recorded with this study may be slightly unrepresentative of the actual shrimp loss resulting from a trawl using the Nordmore grate as opposed to a commercial trawl. There is an unaccounted loss of shrimp that is experienced during commercial fishing, this loss results when the by-catch are removed from the sorting belts and shrimp are taken up with the by-catch (Pers. Obs.). In addition, the use of a retainer bag over the grate caused the grate angle to decrease when fishing dense concentrations of shrimp and this had a large influence on the true shrimp loss. These two factors tend to produce an over estimate of shrimp loss whereas the use of a slightly larger mesh in the retainer bag as opposed to the codend should result in an under estimate of the true shrimp loss. With the exception of the grate angle decrease, these influences on the recorded shrimp loss are not expected to be large. This would indicate that reported shrimp losses was over estimated when fishing was performed in dense shrimp concentrations with the use of a retainer bag over the grate.

Catch comparisons for two of the grates (22mm and 25mm) from the alternate haul experiments also indicated high shrimp losses. These occasional high shrimp losses along with the result of a similar mean shrimp length caught with the commercial trawl and experimental trawl (using either grate) indicate

that shrimp loss consists of shrimp from all length classes and not just large shrimp. This is similar to what was found by Karlsen and Valdemarsen (1989) where shrimp loss with a grate of 19mm bar spacing was found not to be size dependent. This may indicate that shrimp losses with the use of a Nordmore grate having bar spacings greater than 22mm is a result of shrimp hitting the bars as opposed to shrimp being unable to fit between them. If this is true, the bar shape and width would have have a large impact on shrimp loss with these grates.

Results from the retainer bag experiment were used to obtain selectivity curves for the exclusion probabilities of the main by-catch species when using the 22mm Nordmore grate. The grate was found to be more effective in reducing the capture of cod (Figure 9) and redfish (Figure 15) as compared to the capture of plaice (Figure 11) and turbot (Figure 13), as evidenced from each species selection range and 100% exclusion lengths. This suggests that the Nordmore grate is more effective in excluding roundfish than flatfish species, this coincides with what was found by Isaksen et al. (1990).

Problems with sharks, ice and jellyfish were anticipated with the use of the Nordmore grate (Brothers, 1992). However, while all of these situations were encountered, only minor problems were experienced. Sharks and ice entering the trawl were occasionally responsible for breaking the guiding funnel outlet string which resulted in increased shrimp loss. A number of handling

problems associated with the use of a grate were also encountered, the most serious of these resulted in damage to the grate and guiding funnel. These damages were produced when the codend and lengthening piece were retrieved during which the grate jammed in the ramp or other deck structures and when the codend was slack and drawing on the lifting strops, attached to the guiding funnel, resulted in the funnel being stretched. These problems were easily corrected with minor adjustments to deck procedures. Jellyfish catches of up to 200 kg/set were encountered but did not produce blockage of the grate.

In summary, strong materials are recommended for use in the construction of the entire Nordmore grate system and caution should be exercised when fishing in ice. A net panel in place of a guiding funnel may allow sharks and other by-catch to more easily exit the trawl as well as distribute the catch over a greater surface area of the grate and, as such, possibly reduce the shrimp loss. Blockage with jellyfish or other species can be detected by close monitoring with Scanmar water flow sensors which can be corrected by increasing and decreasing speed, as was demonstrated during this trip. Some minor operational delays were experienced with changing grates and codends as well as in removing twists from lengthening pieces, however, it is believed that with a brief period of adjustment, the use of Nordmore grates would result in little interference with regular fishing procedure. Moreover, use

of the grate can drastically reduce the work load required to sort the catch, as was reported by the crew on this commercial trip.

The results from the study of square mesh codends indicated a difference in the mean carapace length of shrimp caught with a 43mm square mesh codend as opposed to a 43mm diamond mesh codend (Figure 7). This difference was such that square mesh tended to capture shrimp of a slightly larger length. This finding is similar to what was found in the Icelandic shrimp fishery (Thorsteinsson, 1992) where diamond mesh codends having an average mesh size of 36.8mm and 36.3mm were compared with square mesh codends having an average mesh size of 39.9mm and 35.8mm, respectively. In contrast, results of this study differ from what was reported in the Greenland fishery (Lehmann et al., 1993) where no difference was found in the length distributions of shrimp caught using codends of 45mm square mesh compared with 45mm diamond mesh. The difference found in this study was pronounced only in the area where small shrimp were predominant. However, it was determined that this difference is not large enough to indicate that square mesh will adequately reduce the catch of industrial shrimp. The square mesh codend was found to be difficult to handle with medium to large catches because of its rigid shape. The vessel's crew encountered problems removing the catch from the codend and indicated that overall quality was reduced when it was used (i.e. broken shrimp). However, samples obtained by DFO did not support this

assertion of the crew. The samples indicated that there was no difference in the number of broken shrimp caught with square or diamond mesh.

It appears that square mesh is not an appropriate method for reducing the catch of industrial shrimp. However, the use of square mesh to release the small by-catch that pass through a Nordmore grate requires further investigation. A Nordmore grate is a viable method for reducing by-catches. It also reduced the time required by the crew to sort the catch. However, there appears to be some loss of shrimp, especially with a large decrease in grate angle, and a loss of fishing time when fishing in heavy ice.

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