By-catch reducing trawls in the North East Atlantic fisheries – the contribution by the University of Tromsö

By

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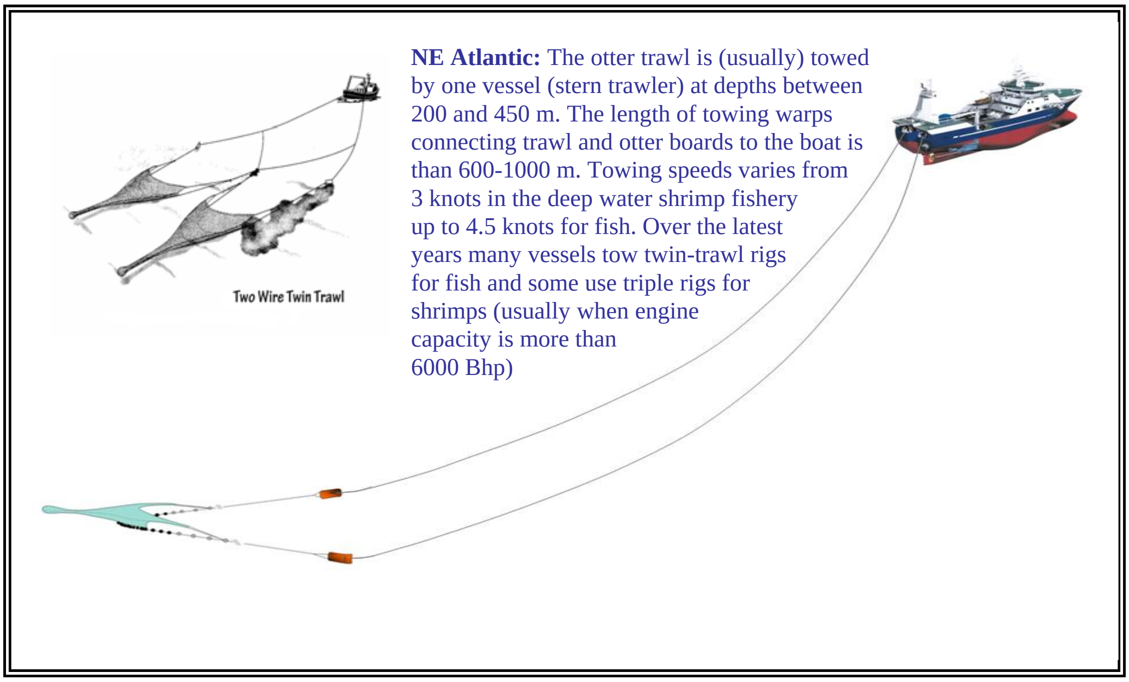
Introduction:

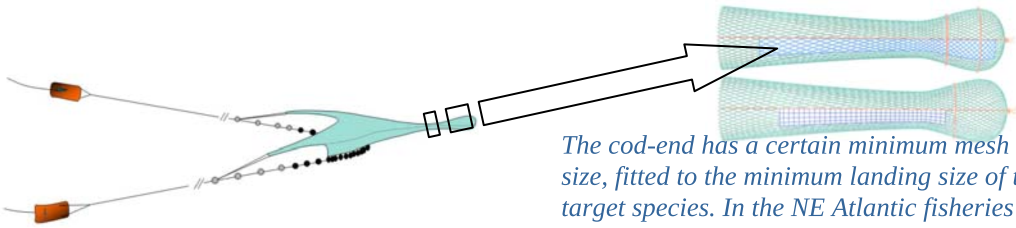
Modern trawls may be visualized as a funnel of (synthetic) net towed by a vessel (or two vessels) through the water. Some trawls are dragged along the seabed or close to it (i.e. bottom trawls), and some are towed at any depth in the free water column (i.e. pelagic trawls). Trawls are by their nature one of the least selective fishing methods used, and usually all fish and crustaceans entering the mouth of the net will be retained.

Trawl fisheries have world-wide been banned by public opinion during several decades due to their catch characteristics, i.e. catching almost all sizes and species of fish in the vicinity of the trawl. On a world scale most trawl fisheries are developed as an effective industrial method to feed the on board factory or processing plants ashore. In many areas modern trawling is disputed.

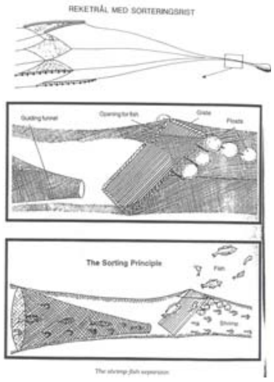


A modern trawler of the NE Atlantic towing a typical bottom trawl for fish (drawings are not scaled)

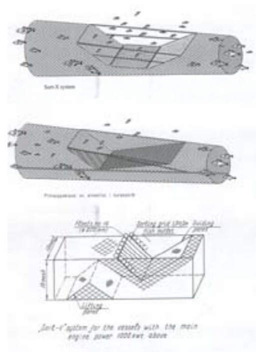
A special focus has been set on the way by-catches have been discarded or dumped from the catches of target species. In a report by Dr. Lee Alverson et al. (1994), the estimated annual dumping of aquatic organisms was calculated to exceed 27 million tons. This is close to 30% of the annual world-wide landings of fish, which is believed to have reached a maximum of just above 110 million tons a year (and approximately 85 million tons are harvested in the marine fisheries).



The cod-end has a certain minimum mesh size, fitted to the minimum landing size of the target species. In the NE Atlantic fisheries a sorting grid is also compulsory



Mandatory sorting grids are made in many qualities and sizes. Most are made from steel or plastics. For shrimp trawls (left) the maximum bar spacing should be 19 mm for the excluder device, whilst the fish trawl grid (right) should have a bar spacing of minimum 55 mm. A grid made from plastics and fibre glass is also available for the cod fisheries.



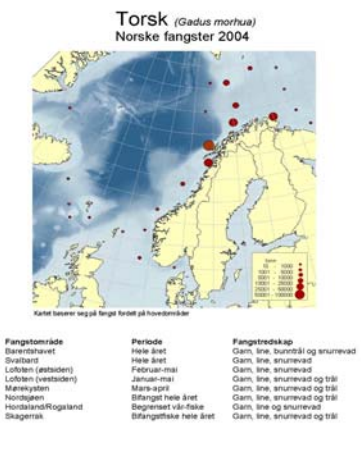
There is a major concern among the world's leading scientists and many people involved in the fisheries sector, that several species already are overexploited. Future generations on our planet may not be given the same possibilities for harvesting the oceans as us. Hence, the Fisheries and Agriculture Organisation (*FAO*) of the United Nations published *the Code of Conduct for Responsible Fisheries* in 1995, which is a document that "sets out principles and international standards of behaviour for responsible practices with a view to ensuring the effective conservation, management and development of living aquatic resources, with due respect for the ecosystem and bio-diversity".

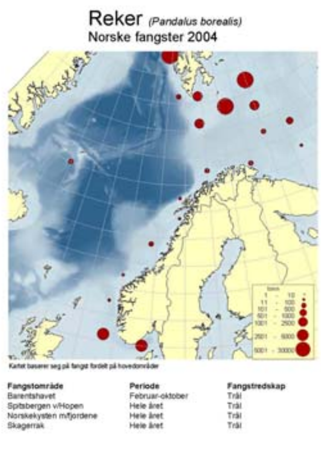
It is acknowledged that technical regulations on fishing gears are important methods to conserve fish stocks and retrieve a maximum yield from commercially important species. Specialists in many countries around the world are therefore continuously working hard to develop more selective fishing gears. Their final aim is to fine-tune the catch properties of fishing gears to reduce, or minimise, meaningless discarding and dumping of important food resources. Despite this effort, there are numerous reports about illegal high-grading and dumping. The drive and need for developing more effective and "rational" technology inside the trawl fleets is often associated with larger vessels, more engine power and larger and heavier component of the fishing gear. This development is in contradiction to the intentions of reducing fishing pressure on important stocks and possible effects from the impact on the seabed. Every fisherman understands the negative consequences of overexploiting fish stocks, but (especially) the trawl technique is a kind of tool for gathering fish and crustaceans that makes it “difficult to make an omelette without breaking eggs”.

In my country the fisheries are important to the nation’s economy and they are a major socio-economic factor to all coastal communities. Our authorities have therefore taken great notice of advises from international bodies such as the UN and the International Council for the Exploration of the Sea (*ICES*). The ICES, by the way, was formed 84 years ago (1902) as, at that time, the leading fisheries biologists were worried about the technical development of the European fisheries, i.e. the fact that trawls became a common and popular fishing method.

Despite disputed, the development of modern and very efficient trawls, and other mobile fishing gears, may be the most important factor to explain decline in stock sizes. Therefore, the importance of methods to avoid by-catch of juvenile and undersized fish has been stressed. Minimum landing sizes for most of the important fisheries in the North East Atlantic are given, and rather severe penalties are given to deter law-breakers. The Norwegian development of rigid sorting grids for trawls (and some other gears) started in 1989, and the technique has successfully been implemented in several fisheries since then (also outside the NE Atlantic).

From the fisherman’s point of view the use of selective devices may be very practical as they remove unwanted and illegal catches. The use of selective devices gives fleets access to fishing grounds that otherwise would have been closed due to for instance high numbers of juveniles. By selecting species or sizes that are better paid there’s also an economic incentive to use conservation oriented fishing methods. Also a cleaner fishery saves sorting labour and can increase the efficiency on the target species.





Landings by Norwegian vessels of cod (Gadus morhua) and deepwater shrimps (Pandalus borealis) in 2004 (Cod = Torsk and Shrimps = Reker). Most of the catches derive from the NE Atlantic. Several methods are used to catch cod, whilst the shrimps are caught only by bottom trawls.

Shrimp trawls (species selective devices)

Retrospect:

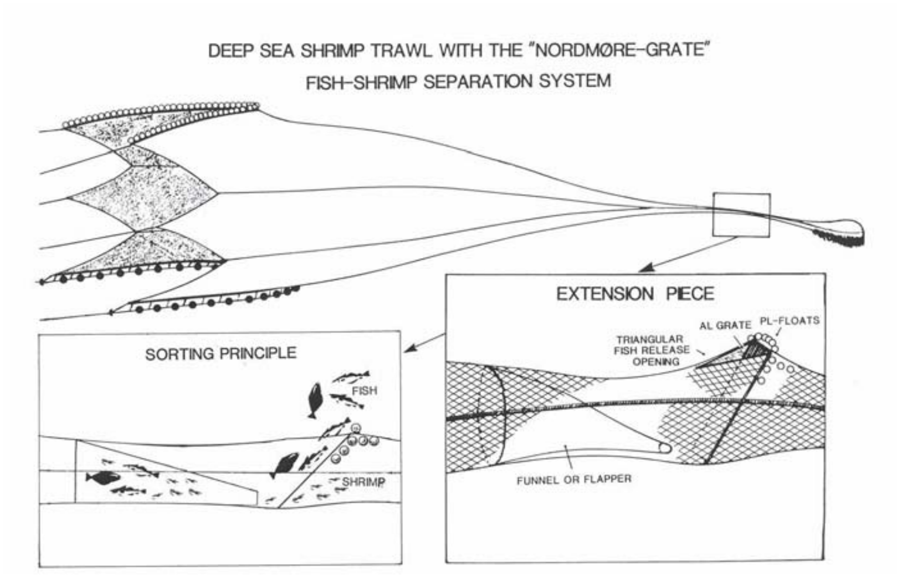
The northern shrimp fishery is made entirely by otter trawls in the North East Atlantic, with large trawls (i.e. sizes up to ∅4000 meshes x 40 mm). The cod-end mesh size is, however, as small as 35 mm (inside, full mesh). The deep-sea fishery for the small northern shrimp (*Pandalus borealis*) developed rapidly during the 1970'ties in Norway. Soon after due to rather large quantities with non-marketable by-catches of juvenile fish from commercially important species, major criticism of this fishery arose. For the fishermen, most of these by-catches represented a lot of wasted energy and time consuming effort to sort the catches and retain the shrimps for further production.

Throughout the 70'ties and the 80'ties different techniques with mesh panels were tested. By the mid 80'ties a sorting panel made of (flexible) net in the aft end of the trawl became mandatory for certain coastal shrimp fisheries in Northern-Norway. Most of these techniques, however, gave fishermen more practical problems compared to the advantages they gained in removing by-catches. The real breakthrough came in 1989, as a fisherman (Mr. P. Brattøy) gave scientists the idea of a rigid metal grid to remove unwanted by-catch. The grid was originally developed as a "blubbershute", i.e. with the one and only purpose of removing troublesome jellyfish from shrimp-catches. The jellies can appear in large quantities in some areas and due to their volume hence break the small coastal nets used if not effectively removed during fishing. The development of the grid was organized as a co-operation between the Fisheries Directorate (Bergen), NTNU (Trondheim), IMR (Bergen), NCFS-UiTö (Tromsø) and Fisherman's Union.

From the very beginning, the experiments with *the Normöre grid* became successful in reducing by-catches in shrimp trawls. Less than 1 year later the *Nordmöre grid* was introduced in the legislation for the coastal shrimp fleets in Norway. By 1 January 1993 the legislation covered the whole North East Atlantic (i.e. Barents Sea, including the waters around the Spitzbergen islands).

Working principles:

The basic idea of the shrimp/fish separator grid is to retain all small specimen (i.e. the targeted shrimps) and exclude all larger specimen (i.e. by-catches of fish) through an exit (opening) in the upper panel of the trawl. The *Nodrmöre grid* can be classified as a *species selective device (or by-catch excluder)*, i.e. separating shrimp from fish. The working principle of the *Nordmöre grid* is shown on the drawing below. The grid is installed in the aft end of the trawl at an angle of 45-50 degrees. The bar distance in the grid will decide the selectivity characteristics of it. In Norway a maximum bar spacing of 19.0 mm has been used to select the usual sizes of shrimps (100-300 shrimps/kg). In other areas with larger shrimps, for instance in the Canadian and Icelandic shrimp fisheries, mandatory bar spacing of 28 and 22 mm are used.

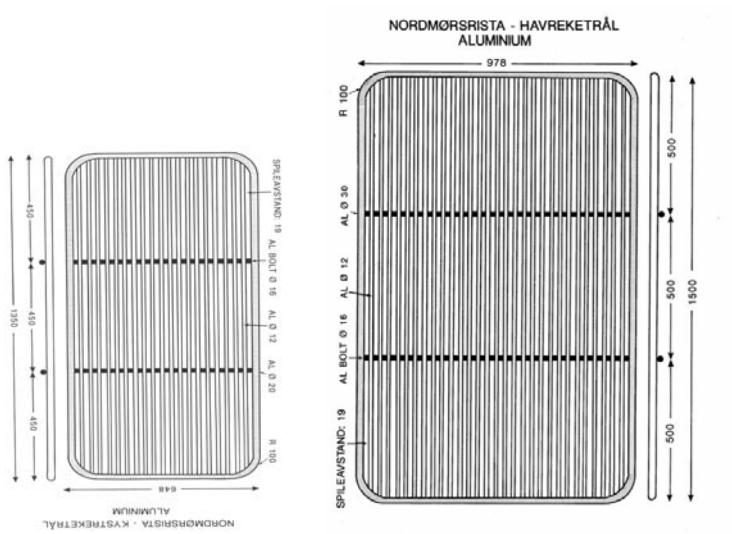


Today the technique is used by fishermen in Canada, USA (Alaska), Iceland, Faroe Islands, Greenland and even in NSW Australia, where the Nordmøre grid is introduced on a voluntary basis to reduce by-catches of commercially important finfish from prawns in the estuarian fisheries.

The working principle of the Nordmöre grid (grate)

Without the effective fish/shrimp separator in the shrimp trawl, probably most of this fishery would have been shut down by the mid 1990ties in order to protect the strong year-classes of juvenile codfish species in the Barents Sea at that time. The introduction of the *Nordmöre grid* in our shrimp fisheries is regarded to be one of the most significant technical regulations in our areas over the past decades, as the grid is able to reduce by-catches of fish on average by more than 95%. As a matter of fact, today very few of our fishermen would even think of the possibility of using shrimp trawls without the by-catch reducing grid.

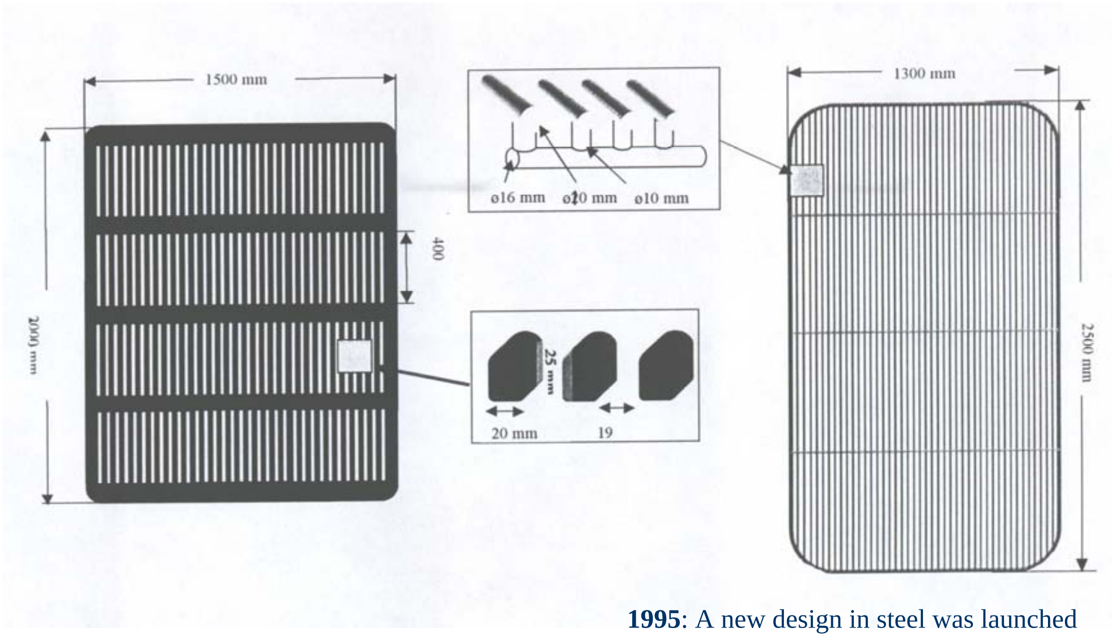
Since the start of development of the *Nordmöre grid* and its introduction, the University of Tromsö has played an active role in further developments of the technology. Most of the work has been made in close co-operation with the managing body of fisheries; the Fisheries Directorate, making some of the legislation process faster. Of the more important steps, some milestones could be mentioned.



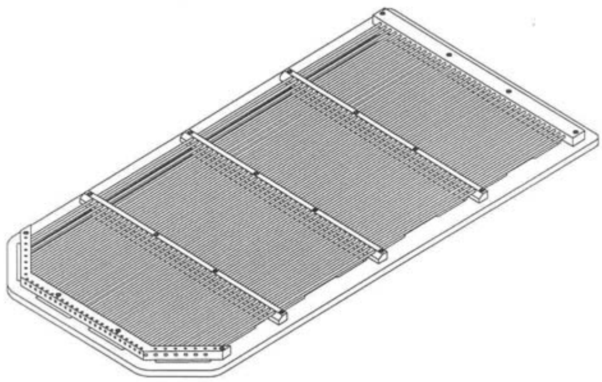
1989/1990: The first designs of the grids for small and large vessels were from aluminium. Ludvig Karlsen, NTNU, designed the first grid.

1991: Offshore vessels started to use steel grids (1.5 m long).

1989-2004: During the whole period many studies were made to improve the function of the grids and to measure their selective characteristics during changing conditions.

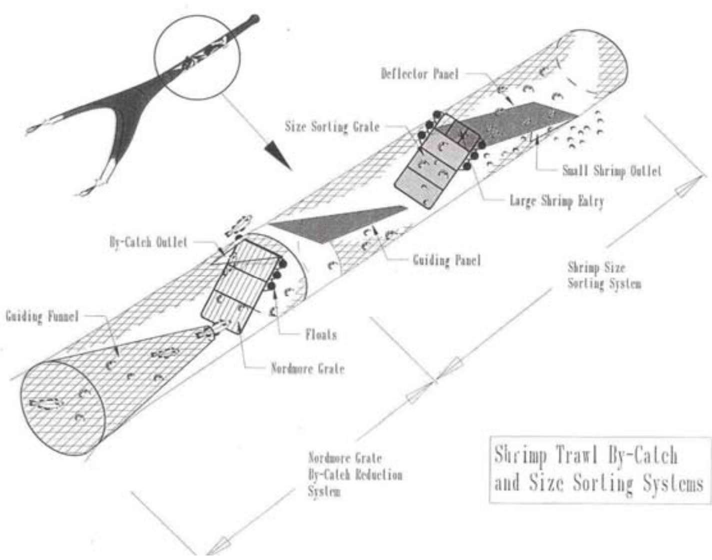


1995: A new design in steel was launched (upper right). The length of the grid was 2.5 m with a weight close to 95 kg's. Fishermen were pleased about the function of this device.



2000: Results with a Canadian type of plastic (hdPE) grid was approved after several tests (upper left). Many fishermen claimed later that the High Density polyethylene plastic was too soft and they wanted more rigid devices.
Also a coastal size hdpe grid was tested with good results.

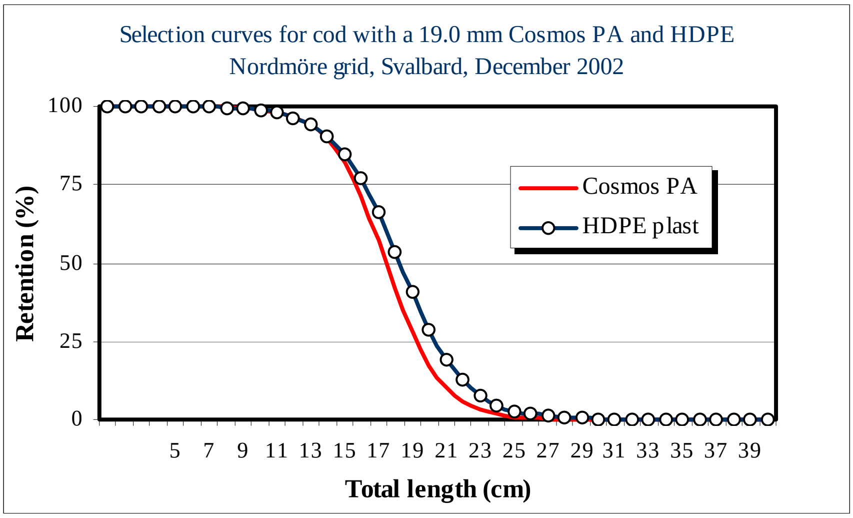
2002-04: Two different models of a Danish design (Cosmos) were tested and accepted by the authorities. The Cosmos grid is made from a frame of nylon (PA) and the bars are made from fibre glass. The device performs well.



1994-2005: Throughout the period many different devices were tested to improve the selection characteristics of the shrimp trawls. Some of the systems were aiming at removing both fish (species selection) and juvenile shrimps (size selection), as shown in the left drawing from Canada. None of these systems have proved to be of interest for the shrimp fleet in the NE Atlantic.

Effects in practical fishing

On average more than 95% by volume of the by-catch of fish is excluded with the *Nordmöre grid*. Effective exclusion of the smallest fish of the same size as the targeted shrimp, is yet to be fully solved. Experiments over a long period focused at fine-tuning the selection characteristics of different models and around the year 2000 different types of plastics were introduced. The high density polyethylene (HDPE) had good sorting effects, but fishermen claimed that the plastics were too soft and that seaweeds, debris etc. reduced the effects. Therefore a grid made from stiffer plastics, i.e. polyamide (PA), with bars of fibre glass was introduced.



The selection curve might be seen as a graphical presentation of the efficiency of the device for different sizes of fish.

The curve is estimated as a probability curve, showing the chance for fish$_j$ being retained given fish of size $_j$ enters the trawl.

This example show the probability for retaining cod (Gadus morhua) at given sizes. All cod larger than ≈23 cm are excluded (0% retained), while all fish smaller than ≈10 cm will pass through the grid and be retained (100% retained). The middle selection point are 17-19 cm with selection ranges of ≈4 cm.

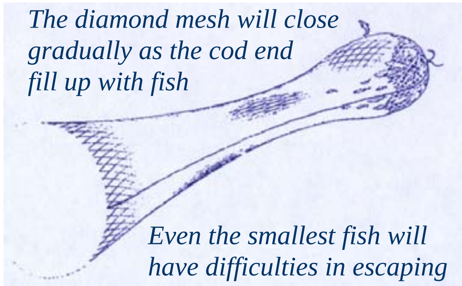
The table below show selectivity results from various trials with 19.0 mm *Nordmöre grids* for different species during trials with shrimp trawls along Svalbard. Results are given as middle selection point ($L_{50\%}$) and selection range, SR, ($L_{75\%}$-$L_{25\%}$).

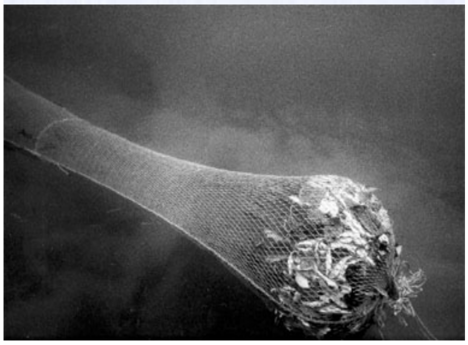
Grid	Cod		Haddock		Saithe		Greenland halibut		Redfish		Long rough dab		Polar cod	
	$L_{50\%}$	SR	$L_{50\%}$	SR	$L_{50\%}$	SR	$L_{50\%}$	SR	$L_{50\%}$	SR	$L_{50\%}$	SR	$L_{50\%}$	SR
Steel, Aug. 1995	-	-	-	-	-	-	-	-	13,0	1,5	19,0	6,0	15,0	6,0
Steel, Jan. 2000	**12,6**	**5,2**	**14,4**	**2,8**	-	-	-	-	-	-	-	-	16,5	4,5
HDPE, Jan. 2000	**17,3**	**4,1**	**13,0**	**5,0**	-	-	-	-	-	-	-	-	27,3	-
Steel, Dec. 2000	-	-	-	-	-	-	-	-	14,1	1,6	-	-	-	-
HDPE, Dec. 2000	**16,9**	**5,0**	-	-	-	-	-	-	**14,0**	**2,6**	14,3	7,3	16,1	11, 2
HDPE, Dec. 2000	**18,5**	**4,2**	**15,3**	**5,5**	**15,0**	**5,1**	**19,3**	**7,2**	**12,9**	**5,3**	14,1	7,4	21,2	12, 1
CosmosPA, Dec. 2002	**17,4**	**3,6**	**13,6**	**4,9**	**14,5**	**4,8**	**17,0**	**7,7**	**13,4**	**3,4**	13,8	8,3	18,6	6,2

Bottom trawls for fish (size selective devices)

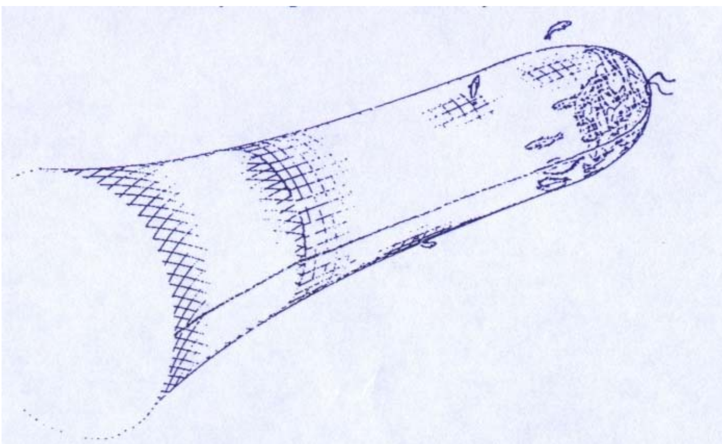
Retrospect:

In most areas of the world fish trawl are regulated with a minimum mesh size in the cod-end (the aft bag of the net) to allow fish smaller than the minimum landing size to escape. Ever since the trawl was introduced it has been obvious that the physics of a conventional diamond mesh cod-end does work very well in size selection. Many attempts to improve the gear have been made. The most common way to improve size selection is by increasing the mesh size.





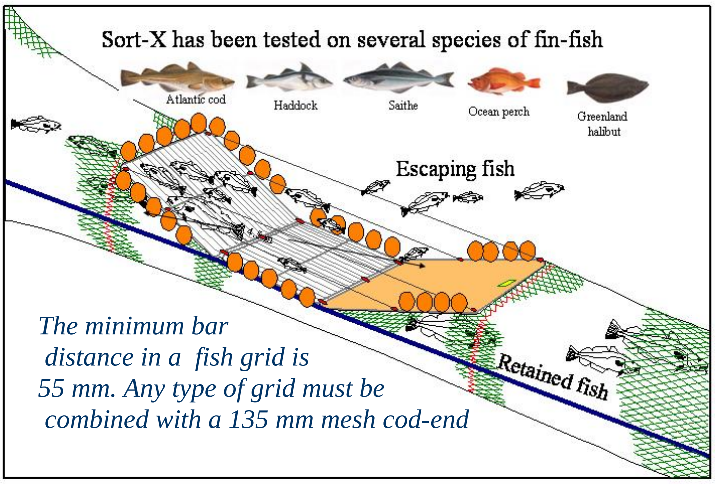
History has shown that the effect of altering the size of the diamond mesh is usually unrewarding from a selectivity point of view. Therefore in the middle of the 1980'ties the square mesh cod-end was tested in several fisheries in Europe and North-America. This type of cod-end was tested in the period 1985-1989 in the NE Atlantic, but he results were far from encouraging. At medium and large catches and in mixed species fishery the performance of the square mesh was worse than with diamond mesh. Additionally, practical problems during handling and knot-slippage (changing the mesh shape) made this cod-end impractical from a management point of view and no further test were made with it in fish trawls.



The full length square mesh cod-end was during trials proven to be very successful in reducing by-catches of juvenile haddock and whiting in the Scottish fisheries in the beginning of the 1980ties. Despite the results it never came into legislation, but lately escape windows with square mesh net been used in Scottish cod-ends. Modified square mesh cod-ends are used in parts of the Norwegian fisheries with Danish seines.

Encouraged by the development of the *Nordmöre grid*, we started a pilot test with a size selective sorting grid in late 1989 with promising results. The aim was to develop a *size selective sorting grid* for fish trawls targeting the important cod fish species of the Barents Sea, i.e. cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and pollack (*Pollachius virens*).

The working principle of the Sort-X is shown below. This sorting grid works in a reverse way compared to the *Normöre grid*, and the challenges of a successful result is somewhat, or quite, different from the species selective grids. Opposite to the mechanical sorting principle of the species-selective fish/shrimp separator grid (i.e. *the Nordmöre grid*), the function of the *size* sorting grids will depend on fish behaviour and the “co-operation” from individual fish. From underwater observations it is suggested that escape through the grids is a result of the change in light penetration through the trawl and water-flow through the grids.

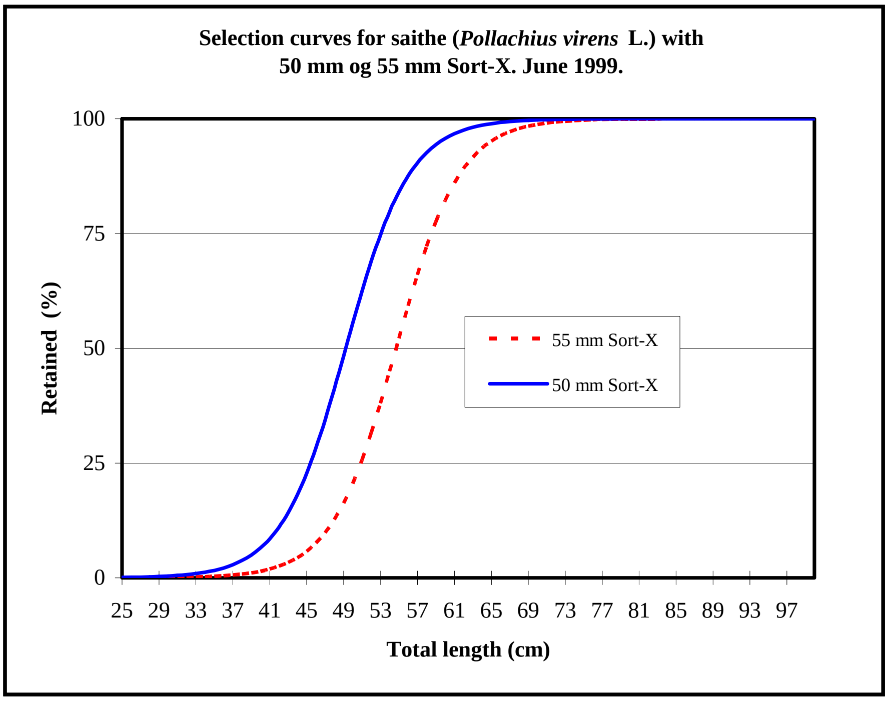


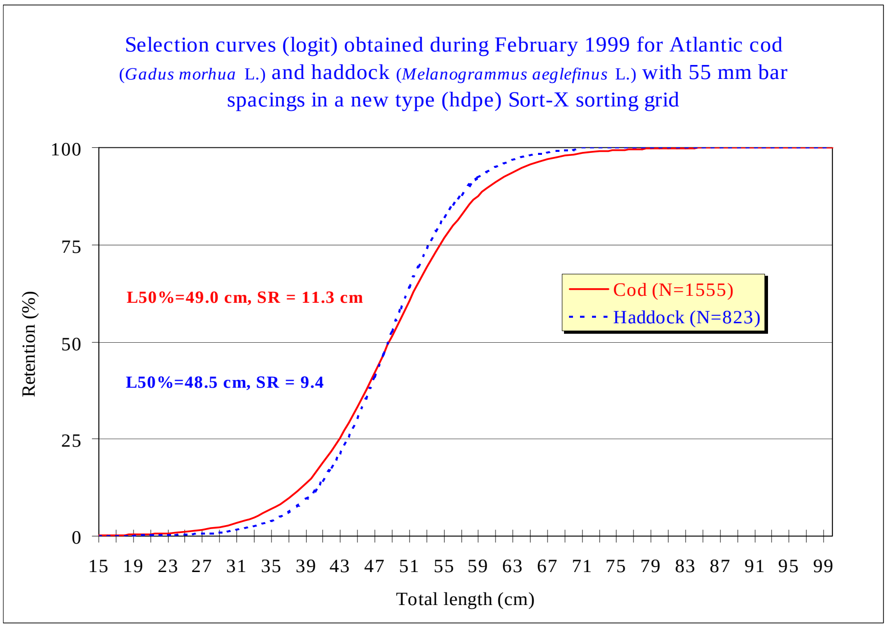
Fish grids are attached to conventional bottom in front of the cod-end (and extension).
In the period 1995-2000 several trials were made in the North Sea with smaller sizes of the grid system and good sorting results were obtained. The use of sorting grid is not mandatory in this area.

After the Sort-X grid became mandatory, several other grid systems are developed. Today the most frequently used grids are a Norwegian version of the Russian Sort-V device and a flexible plastic grid.

During the period 1990-97, several experiments with sorting grids (i.e. Sort-X) were made on board a wide variety of commercial Norwegian and Russian trawlers. In total more than 500 days of sea-trials were made, gathering information’s on both the selection characteristics of the Sort-X on different species and on how the sorting grids could be used (or utilised) by fishermen. Norwegian fishermen started to use the Sort-X in 1993, to reduce the numbers of small fish when targeting the cod. Since 1 January 1997 the use of sorting grids became mandatory in parts of the NE Atlantic, i.e. the Barents Sea.

The bar distance of the grids will decide the sizes of fish to be retained, and in the Barents Sea a minimum bar spacing of 55 mm is chosen, which gives a 50% retention length for cod and haddock close to 50 cm. The minimum landing sizes of these species are 47 cm and 44 cm, respectively. At small and medium catches the 50% retention length is almost the same in a 55 mm sorting grid as in a cod-end with a 135 mm mesh size. The difference between the two systems is the *shape* of the selection curve, i.e. more of the small fish will escape and more of the legal sized fish will be retained by the grids compared to the normal cod-ends. An example of selection results on saithe using different bar spacing (50 and 55 mm) is shown below.





During trials the grid devices are shown to be superior to other selective devices in producing stable and predictable results during changing conditions, i.e. fish densities, time of the year, weather conditions, vessels sizes etc.

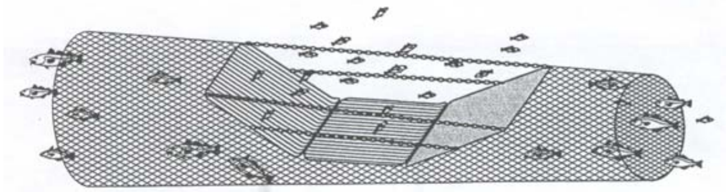
After the grids became mandatory, many fishermen complained about the many practical problems by using these complicated devices. They also disputed the reported effects by them.

Therefore several research institutes started to develop their own versions of grids to meet the criticism.

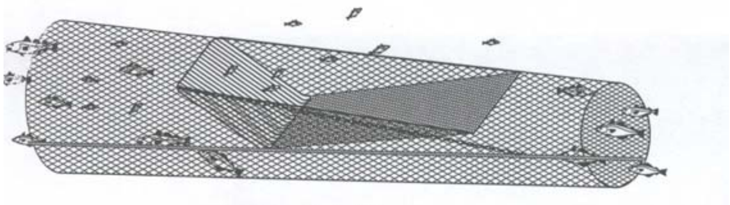
A version of the Sort-X made from plastics was tested, but the device never came into practical use. Instead a better plastic grid was developed by SINTEF Fisheries and Aquaculture. This grid was more user friendly than other systems.

Further development:

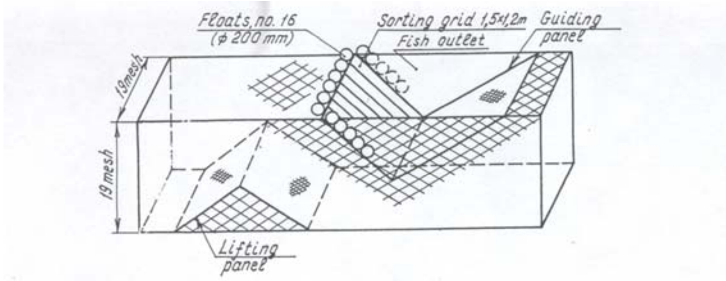
The Russian PINRO in Murmansk started trials with their version of a grid system (the Sort-V made of steel) in 1995, and it was approved in 1997 as a legal system provided used in Russian nets. The Institute of Marine Research in Bergen started the same year to test a modified version of the Sort-V. They named the system “single grid for fish trawls” (and the grid is made from stainless steel). It was approved by 2000. In 1998 the development of the Flexigrid, made from rubber and fibre glass, started at SINTEF in Trondheim. The system was approved 2002. Fishermen can now choose between the three models, but it is believed that the heavy steel grids will gradually be replaced by more user friendly plastics.



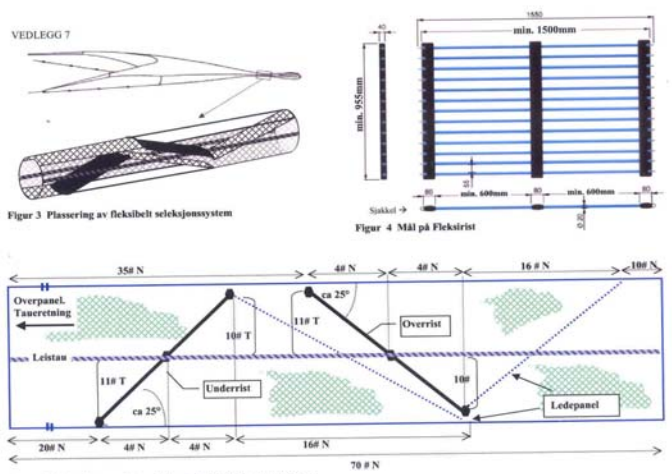
Sort-X system (Tromsö)



Single grid for fish trawls (Bergen)



Sort-V for Russian trawls (Murmansk)



Flexigrid of plastics (Trondheim)

The drawings to the left show three different systems made of (stainless) steel;

Upper: Sort-X (1990)

Middle: Single grid (1995)

Lower: Sort-V (1995)

Size sorting grids for fish trawls builds on the same principle, i.e. escaping fish has to move upwards and away from the trawl. Larger fish will pass/slide under the grid and enter the cod-end in the aft of the trawl.

In the Norwegian fisheries the single grid is widely used, while most of the Sort-X models are replaced by the other versions.

Most Russian vessels are using the Sort-V, but some vessels still use the Sort-X system.

The latest type of sorting grids for fish trawls was developed in 1998-2000 at SINTEF (Trondheim). The system is made from rubber and fibre glass, making the system flexible and very user friendly. The grid-section carries one grid in the lower panel and one in the upper. Especially small cod are seen to escape through the first and lower grid, while other species and sizes tend to escape through the aft upper grid.

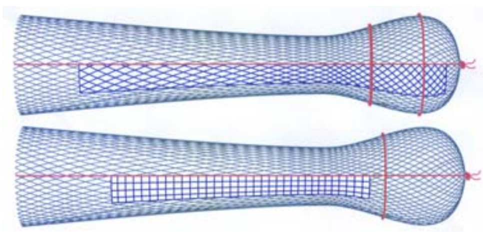
The sorting capacity of the Flexigrid is comparable to steel grids.

Technical measures of fish trawls in the future?

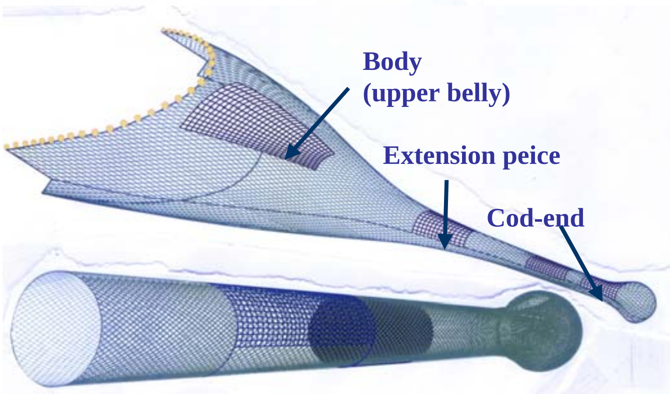
The use of sorting grids have been a valuable tool to solve the by-catch problems of some fisheries, and in my part of the world the development of sorting grids has been welcomed by the majority of people involved in the fisheries sector.

One of the major concerns during the 1980'ties and in the beginning of this decade was that the increasing effort on selective fisheries would be of no use if all escaping fish died during this process. Further research by among others the Institute of Marine Research in Norway have shown that the mortality of escaping fish is close to zero for most species. It is therefore important and necessary to continue the work on by-catch reducing devices in trawl fisheries. Careful management and new methods to conserve juvenile and young fish recruiting the important stocks around the world, may be important keys to maintain the world's marine fisheries of today's 85 million tons level, or hopefully slightly increase it.

The overexploitation of fish bellow marketable size together with the high pressure applied to the mature cohorts has brought most of the gadoid fishing grounds of the North Sea and Baltic Sea to an extremely delicate situation. The important cod-species of the NE Atlantic is considered to have full reproduction capacity but the reduction of the fishing mortality on the juvenile stock and lower discards are still sought. An efficient fishing gear from the selectivity point of view should have a narrow selection range (sharp selection curve) and behave as stable as possible specially with the variation of uncontrollable *or* incidental factors such as the sea state, fish size or species distribution, catch size, etc. This selection efficiency would allow lowering the pressure on the smallest fish sizes, which are normally discarded and seldom survive, increasing the future exploitable size of the stock. The selective properties of a trawl have traditionally been attributed to the mesh size but due to the poor state of the different fishing stocks, the input effort on the development of other alternative selection measures such as grids, escape windows and square mesh cod-ends has increased substantially in the last two decades. The usage of escape windows are mandatory in the Baltic Sea since 1995 and were introduced in the North Sea (as an alternative to bigger



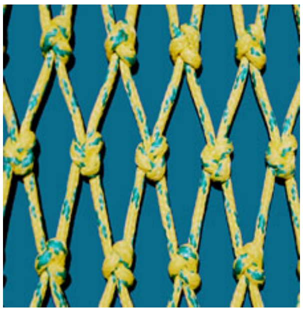
To improve the size selection characteristics in traditional cod-ends areas of "selective windows", i.e. square mesh, Exit Windows or T-90^{o} meshes, may be used. (T-90 is ordinary net (N-direction) hung in the T-direction.



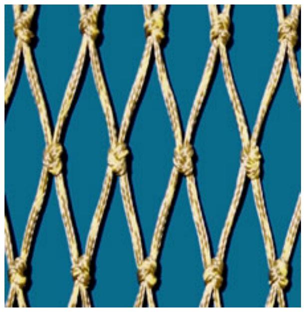
Selective windows may be inserted in the body of the trawl, in the extension piece or in various areas of the cod-end's upper panels. Experiments performed in Scotland suggest that the effect of these windows gets larger when they are located closer to the cod-line (aft end).

diamond meshes) in 2000. In the Barents Sea however, sorting grids were the alternative chosen by the authorities to reduce the juvenile fish by-catch. Thus, the 55 mm bar spacing “Sort X system” selection grid was introduced on a voluntary basis in 1993 and made mandatory in 1997

Investigations for the improvement of the selectivity measures in gadoid fisheries both in the North Sea and in the Baltic Sea have been mostly concentrated on escape windows, whereas sorting grids have been the focus in the Barents Sea. A recently presented study carried out by the Institute of Marine Research of Norway concluded however, that a 155 mm diamond mesh size would give just as good results as a 55 mm sorting grid combined with a 135 mm cod-end. These results open up again the debate of whether the use of the grids is strictly necessary to guarantee an improvement of the selection properties of a diamond mesh cod-end.



Produced by Euronete, Portugal



Information from the producer

“Euroline Premim is 50% stronger than standard braided PE netting and approx. 15% stronger than nylon netting of same runnage.”

Information from the producer:

“Euroline Premium "PLUS" can be used with smaller diameter twines for the same strength. It has good stretch recovery without major deformation and high abrasion resistance. Economical compared to Dyneema and Spectra.”

The selective properties of a trawl have traditionally been attributed to the mesh size but due to the poor state of the different fishing stocks, the input effort on the development of other alternative selection measures such as grids, escape windows and square mesh cod-ends has increased substantially in the last two decades. The usage of escape windows are mandatory in the Baltic Sea since 1995 and were introduced in the North Sea (as an alternative to bigger diamond meshes) in 2000. In the Barents Sea however, sorting grids were the alternative chosen by the authorities to reduce the juvenile fish by-catch. Thus, the 55 mm bar spacing “Sort X system” selection grid was introduced on a voluntary basis in 1993 and made mandatory in 1997.

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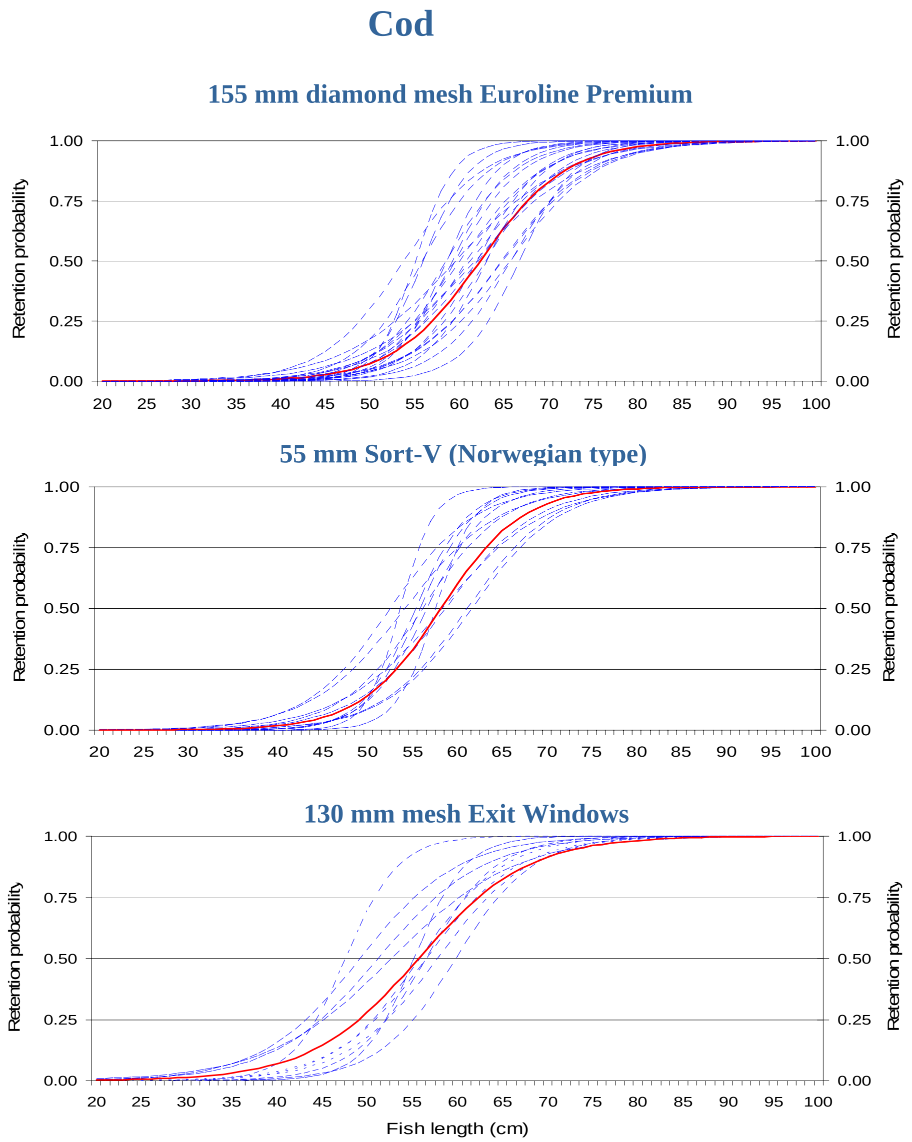
Recently (early 2006) scientist from the NCFS at the University of Tromsö made a study to compare the selective properties on cod and haddock for: a 135 mm (nominal mesh size) cod-end fitted with two lateral Exit Windows; a Norwegian type 55 mm Sort-V steel grid (single grid) combined with a 135 mm (nominal mesh size) cod-end; a

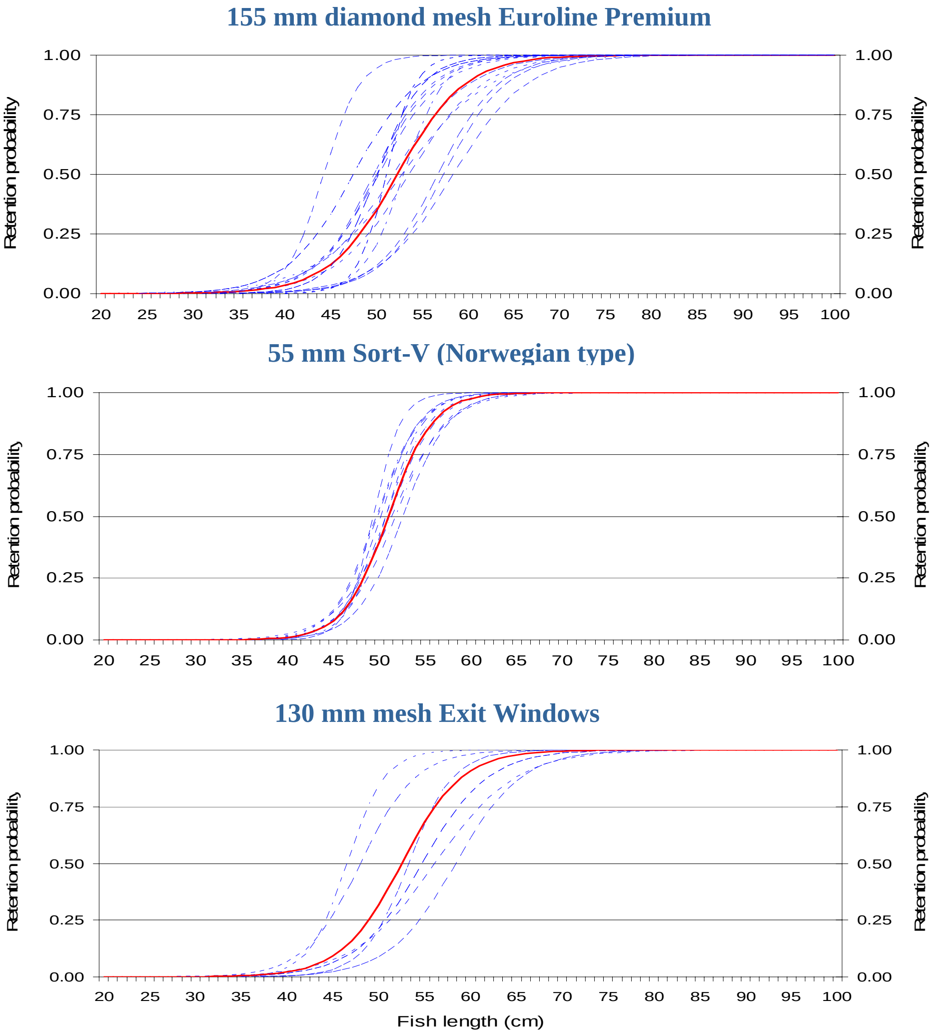
155 mm diamond mesh (nominal mesh size) cod-end made from a new material known as Euroline Premium ("hotmelt"). The trials for the three set-ups were carried out in as similar conditions as possible and trying to mimic commercial activities. The conclusions from these experiments were clear and rather unstable and unrewarding for the new 155 mm cod-end, while Exit windows inserted in traditional cod-ends and sorting grids combined with traditional cod-ends gave good results. Examinations of underwater video show that the new 155 mm type of diamond mesh cod-end maintain more or less closed meshes throughout the haul. It is therefore believed that escape takes place during haulback and as the gear enters the surface.



Note: Compared to the 55 mm Sort-V and the 130 mm Exit windows, the use of 155 mm conventional type of mesh in the cod-end will not improve the selectivity. Figures from Grimaldo et al. 2006.[1]

[1] E. Grimaldo*, R.B. Larsen and M. Sistiaga 2006: Selectivity experiments in the Barents Sea trawl fishery using cod-ends with conventional diamond mesh, sorting grids and escape panels and discussion of possible effects. Proceedings of the NorFishing Technology Conference 2006, Trondheim.

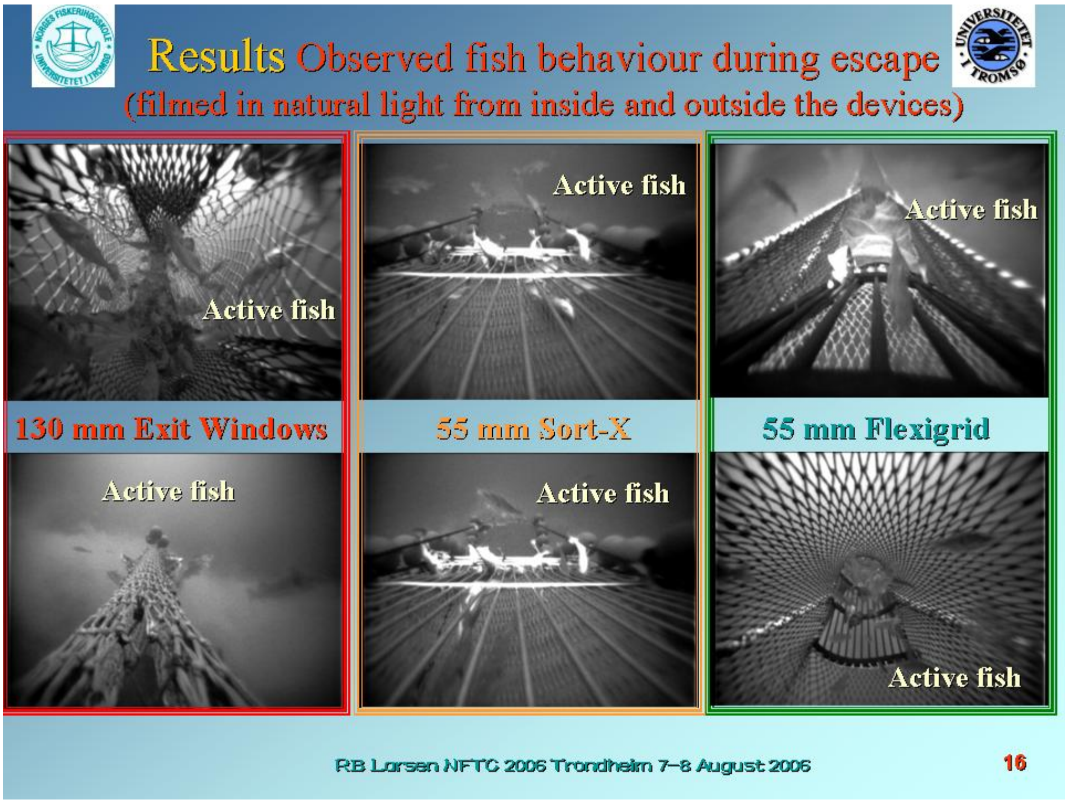
Haddock



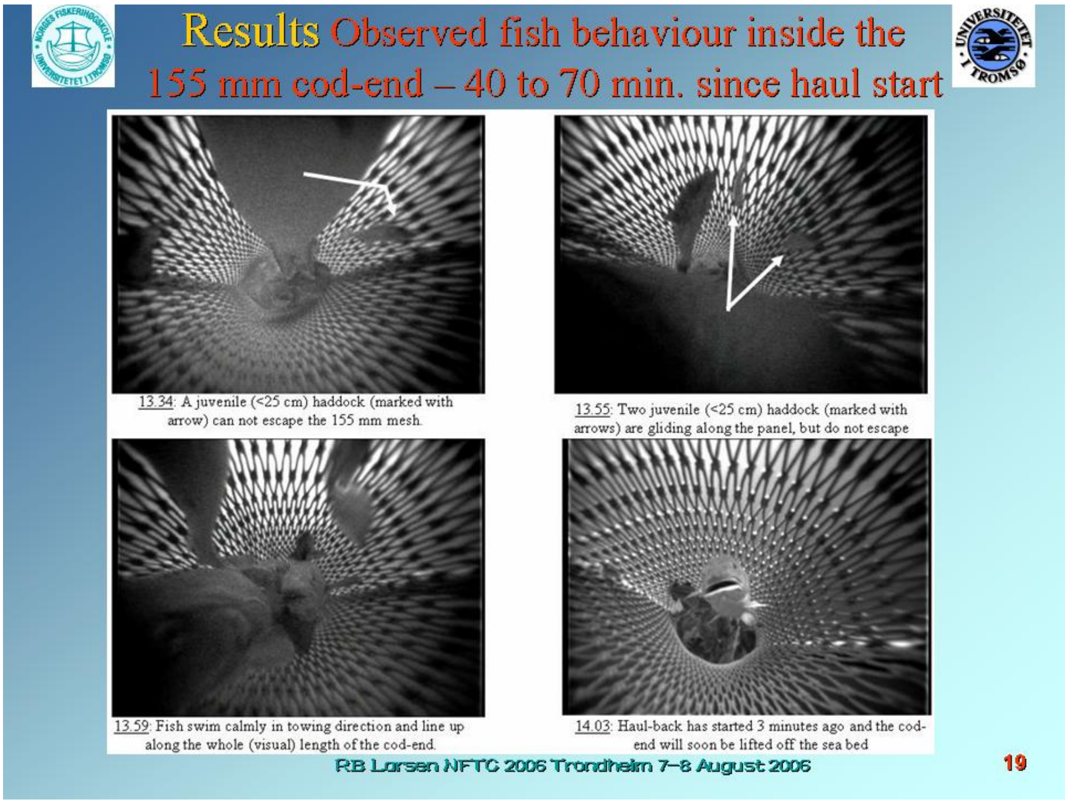
Figures from Grimaldo et al. 2006.

In all types of sorting grids and in the Exit Windows, which always ensures open meshes during fishing, individual fish are very active in finding their way out. In the conventional cod-end with closed meshes fish show no attempt to escape and it is not possible even for the smallest fish to get through the closed meshes during the tow. Only as the cod-end is just below or at the surface some small fish drop out (due to reduced tensions/drag in the mesh direction). The recent results show that the interpretations from any selectivity experiment should be treated very carefully and that fish behaviour during the sorting process must be carefully studied and understood.

At our institute there will be a continuously search for effective devices to solve by-catch problems and we will continue to work with Exit Windows and other systems that perhaps can replace the relatively complicated rigid sorting devices. The final aim is to give fishermen and the management more options to meet the international goals and standards for cleaner harvest in the practical trawl fisheries.



Observations made with underwater cameras show different behaviour of fish from system to system. Fish are typically very active and escape rapidly from sections with rigid grids and net panels with slack (and loosely hung) meshes.



Very few fish were observed escaping during tows from the 155 mm Euroline Premium twine cod-end. If fish caught in deep waters escape at or close to the surface, the survival might be very limited and raise more problems to questions on unaccounted mortality.

Comments and advices:

The latest experiments confirm that both sorting grids and Exit Windows combined with conventional 135 mm cod-ends show stable and good selectivity. The results are in line with results through long series of experiments covering many years.

The results suggest that increase of the mesh size (from 135 to 155 mm) in a conventional cod-end (built from traditional diamond mesh) will have very limited effects on size selectivity.

One simple way of comparing the different systems tested in 2006 could be through the selection factor (SF), defined as middle selection point ($L_{50\%}$) over mesh size (MS). The larger SF-value, the better size selectivity: $SF = L_{50\%}/MS$

	Cod *Gadus morhua*			Haddock *Melanogrammus aeglefinus*		
System	55 mm grid	130 mm Exit windows	155 mm diamond mesh	55 mm grid	130 mm Exit windows	155 mm diamond mesh
$L_{50\%}$	58.2	55.7	62.3	51.0	52.5	52.3
SF	**10.58** **(5.30*)**	**4.28**	**4.02**	**9.27** **(4.64*)**	**4.04**	**3.37**

* The bar spacing in a grid can be considered as roughly a half mesh size.

Note: Even when the mesh size is close to 20% higher in the diamond mesh cod-end than the 130 mm Exit window, the SF for both cod and haddock is lower. Compared to the grid the difference is even larger.

Underwater video-recordings revealed that few fish escape during the catch process from the diamond mesh cod-end. This unrewarding result is most likely a result of the combination of mesh shape and the type of modern, stiff twines used. Moreover, the proportions of escape close the surface through such cod-ends raise many worries for the survival of escapees. If the selective devices fail in allowing escaping fish to survive, selectivity has no meaning. As a result continued experiments we will focus on safe escape processes.

Based on current information, we will give following advices for further technical measures for the northern fish trawls:

- The use of sorting grids combined with (135 mm) conventional cod-ends meet the objectives of technical regulations for the cod-fisheries.
- The use of 130 mm Exit windows in conventional 135 mm cod-ends may be an alternative to rigid devices as they meet the objectives of technical regulations for the cod-fisheries.
- The use of increased mesh size (135 to 155 mm) in a conventional diamond mesh can not be recommended because documented side-effects raise great uncertainty about the effects for responsible fishing practices.
- Any system to be implemented must meet basic requirements of size selectivity, including the welfare and safety of escaping fish (i.e. minimal mortality).