Fish Capture Committee ICES CM 1996/B:1

REPORT OF THE

STUDY GROUP ON GRID (GRATE) SORTING SYSTEMS IN TRAWLS, BEAM TRAWLS, AND SEINE NETS

Woods Hole, Massachusetts, USA

13–14 April 1996

International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

Palægade 2–4 DK–1261 Copenhagen K Denmark

TABLE OF CONTENTS

TABLE OF CONTENTS

Report of the First Meeting

1. TERMS OF REFERENCE

At the 82nd ICES Annual Science Conference held in Aalborg in September 1995 the Consultative Committee adopted a resolution to establish this Study Group under the chairmanship of John Willy Valdemarsen, with the following terms of reference:

a. review current research on grid (grate) sorting systems for different fisheries;
b. identify opportunities for further application of grid (grate) devices to improve selectivity in single species and mixed species fisheries;
c. assess the advantages and disadvantages of grids as selective devices in comparison with other techniques; and,
d. report its findings and recommendations to the Working Group on Fishing Technology and Fish Behaviour, the Advisory Committee on Fishing Management, and the Advisory Committee on the Marine Environment.

2. INTRODUCTION

The first session of the Study Group was held at Woods Hole, Massachusetts, on April 13 and 14, 1996. A list of attendees is given in Appendix I.

Grids are one of the more recently-developed technical means used to influence the size- or species-selectivity of a fishing gear. This can be further characterized as follows:

a. Gross species selection, e.g. shrimp/fish, shrimp/turtles.
b. Finer-scale species selection where size differences are not so extreme, e.g. large shrimp/small fish, various pelagic species, Norway pout/young whitefish.
c. Size selection within a species, e.g. large/small shrimp, mature/juvenile fish.

Assuming a grid has been correctly designed, fabricated, installed, and operated, it possesses several inherent advantageous properties:

a. Fixed geometry. The escape openings are always available and oriented correctly. There is no tendency for escape openings to change size or shape in response to changes in towing (e.g. towing speed, door spread) or fishing conditions (e.g. increasing catch volume) so the grid's selectivity properties are more stable than is commonly found with flexible selection systems constructed of netting. Depending on construction and mounting, grid systems may be easier to modify or shift from trawl to trawl than large, sewn-in netting panels or sections that serve the same function. Finally, grid systems are relatively easy to precisely describe and inspect for the purposes of fisheries management and regulatory activities.
b. At least from a theoretical standpoint, the elongated escape openings and smooth surfaces featured in grids may be more conducive to successful escapes and escapee survival relative to selection systems constructed of netting.

c. The rigid structure lends itself to innovative secondary uses such as stable mounting points for leading panels, scaring devices, or specialized instrumentation. Depending on construction and operation, grids can also be used for keeping debris, sponges, or other large items out of the codend.

Grids possess various limitations and disadvantageous characteristics as well:

a. They may be inconvenient or even dangerous to use in certain fishing situations. For example, it may be difficult to design a grid that can be conveniently used on a net drum. Also, if catches are commonly large in a fishery, it may be necessary to construct the grid so heavily that it becomes a menace to the crew during onboard gear handling operations.

b. Often (but not always) grids may be more expensive or troublesome to install, operate, and maintain than alternative "soft" solutions. For example, in addition to the expense of the grid itself, most grids are negatively buoyant and so must be rigged with extra compensating floats, adding to expense, bulk, and maintenance needs. Many fishermen using grids have found it necessary to purchase costly grid angle sensors in order to ensure correct function during the haul. Many grid designs are not "self-righting" so extra care must be taken during shooting to ensure that the grid is correctly oriented, with no twists in the trawl body in front of it.

There are numerous alternative techniques for manipulating the selectivity of towed fishing gears which have been developed and employed over the years.

Many trawl construction features have been developed for improving codend selectivity by increasing the average opening of the meshes in the codend: increased mesh sizes, square mesh codends, shortened lastridge ropes, other framing/supporting ropes installed in the codend, reduced codend circumference, etc. This approach relies mainly on passive (or semi-passive) mechanical size selection for its functionality and offers little likely species-selection benefits except where gross size differences exist among the species encountering the gear. It has no value at all where the target organisms to be retained in the catch are smaller than the ones that are to be excluded. There has been considerable difficulty in translating selectivity findings from such studies into practical use by fishermen or fisheries managers, or for that matter resolving differences in findings obtained in different selectivity studies.

Escape windows of varying materials, placement, and construction have been tested, often successfully. This approach relies more on behavioral effects and active escape behavior, although some size-selection can secondarily occur here as well depending on the nature of the window. Such techniques (when they work) are typically among the cheapest and easiest to use in practical applications.

Much research effort has been focussed on developing guiding panels made of netting that are intended to selectively lead animals towards an opening, a second codend, etc. This approach can rely on a combination of active and passive sorting, with impacts on both size- and species-selectivity. Such systems have characteristically worked better in a research setting than they have in commercial use, but they do offer the potential advantage of being relatively cheap and easy to use.

Prior to the meeting, the Study Group's participants were asked to consider the following points:

- Is it true (or at least likely) that grids offer measurably improved escapee survival rates? Experiments conducted in Finland and Norway did not find any differences. The Finnish results suggested that a herring's fate was already determined by the time it reached the extension section where grids, large-mesh codends, or other selectivity devices are typically installed. The Norwegian results with cod and haddock found high survival rates regardless of what selectivity device was employed. Is there other research on this topic?

- What do we know about the behaviour of fish or other organisms with respect to grids? Can behaviour be manipulated through grid design to affect selection?

- What research is needed to broaden or improve applications of grids?

- What are the specific factors leading to a probable successful application of grid technology to a particular situation?

- Assuming grids and "soft" solutions offer equal potential functionality, when is a grid the preferred solution? What are the acceptable compromises in functionality? For example, how much better must a grid perform in order to justify a purchase cost higher than that of an escape window?

- What new methodologies, measurement capabilities, etc., are needed to advance grid research or effectiveness? A grid angle and speed sensor has already been developed and marketed, and fishermen have found innovative uses for this. What other specialized instrumentation (if any) would be desirable, either for research or commercial use?

Engineering considerations:

a. Materials for grid construction. Aluminium, stainless steel, fiberglass, plastic, and tensioned wires (to replace the bars) have all been tested or at least considered. Are there other likely candidates? What are the advantages and disadvantages?
b. Construction features such as hinges, cross-braces, other stiffening techniques, etc. have been tried or could be developed. What considerations are most important? What about different grid shapes or installation procedures?
c. Hydrodynamic effects. What are the impacts of changes in the hydrodynamic regime due to the grid system on overall trawl performance and function? Can the hydrodynamic regime within and near the grid system be deliberately manipulated to affect selection processes?

3. REVIEW OF CURRENT RESEARCH (national progress reports)

3.1 Belgium

To the present date no experiments have been done with grids in Belgium, and there has been no commercial application of any grid system. However there is increasing interest in by-catch reduction devices for the Belgian shrimp fishery, especially from the management side. Shrimp is the target species for beam trawlers with low (below 300 hp) engine power ratings fishing in the coastal zone. Depending on the season, important by-catches occur of commercial and non-commercial species and benthic organisms.

In 1995 the Fisheries Research Station in Ostend started up a bycatch reduction program for this coastal shrimp fishery. The research program consists of four phases: 1) descriptive inventory of shrimp vessels, fishing gear, and catch handling; 2) determination of the whole trawl selectivity of the shrimp beam trawl; 3) a program to sample by-catch and/or discards in this fishery; and, 4) trials with by-catch reducing devices, especially grids and sieve nets. Phase 1 is finished and phase 2 is well underway with first results expected soon. Phase 3 was set under way in March. Phase 4 is in preparation and first sea trials are anticipated in November of this year. Different grid design variations will be tested, but the basic type of grid to be used would be the Nordmøre grid. Gross species selection and finer scale species selection are envisaged. Initially the material will be plastic, and bar spacing will be between 10 and 15 mm. Since the by-catch contains commercially important species like sole, plaice and cod, it must be sorted into a second, large mesh codend. Problems have been reported with such second codends but in this situation they will be required.

3.2. Canada

3.2.1. Review of grate research efforts in Nova Scotia

Shrimp grate research was initiated in 1990 with promising results, both on research & commercial vessels. Grates were made mandatory for all shrimp vessels in 1991, with permissible bar spacings of up to 25 mm. Shrimp fishermen like using the grates because of the reduced need for catch sorting. There is no incentive to cheat since the vessels have individual transferable quotas (ITQ's) for groundfish and they do not want to catch groundfish while shrimping. Guiding funnels are not always used; sometimes simple guiding panels are employed or there may be no guiding system at all.

Grates are also used in the silver hake fishery, mainly by foreign (Cuban, Russian, etc.) boats. These vessels have small bycatch quotas for cod, haddock, & pollock. The grates worked well during the initial trials; at 40 mm interbar spacing capturing 95% of the hake and releasing 95%, 92%, and 87% of the pollock, cod, and haddock respectively. Another test compared different bar spacings and arrangements: 40 mm vertical (normal), 40 mm horizontal, and 50 mm vertical. Camera studies showed that more hake contacted the horizontal bars. With 50 mm spacing more silver hake were captured, but pollock escapement fell from 95% to 67% and cod and haddock bycatches increased as well. Shorter spacings between the end of the funnel and the grate were also tested, with improved hake catch. Tests were conducted on the system's sensitivity to grate operating angles. The system still functioned when angles were reduced to 25 degrees, but catching efficiency for silver hake decreased. The Cubans are using 70 degree angles now. The material used in the tunnel had a big impact on fish condition; smooth knotless netting caused less damage to the fish in the catch. Large fish such as sharks have caused a lot of damage to the grid and the region around it, so the Cubans are fitting some trawls with largemesh barriers across the net mouth. No problems have been seen with skates or other objects or organisms blocking the grates.

One cruise was conducted to test the Sort-X system on redfish and cod. High concentrations of fish were encountered, and catch rates were very high. Results were poor which may have been due to incorrect installation and/or large quantities of fish at or near the L50.

Discussion:
It was pointed out that tests done in Norway showed large shrimp losses when the funnel was eliminated, and such losses also occurred when Nordmøre grid angles were reduced below 40 degrees. US fishermen have found that sloping panels suffer less from blockage than funnels.

A concern was expressed that ropes or bigmesh panels across a trawl's mouth tend to change the net's geometry, and may also deter target species from entering the trawl. The group was informed that in the past some Norwegian boats used to employ large mesh bags within the trawl body but in front of the codend to strain out sharks and other large objects.

3.2.2. Review of grate use in the Gulf of St. Lawrence, Newfoundland, and Labrador regions

Shrimp size selectivity research is underway in the Gulf of St. Lawrence shrimp fishery by vessels between 13 and 20 meters (see paper in Appendix II), and in the northern offshore shrimp fishery by vessels between 50 and 75 meters. There is a price premium for larger shrimp which helps motivate selective harvesting. Mesh selectivity reduces the bycatch of small shrimp but with a penalty in terms of losses of large shrimp, while square mesh results in greater breakage. Codend side panels made of stiff, plastic coated netting have been tested, but underwater TV showed no escapement. Tests have been conducted with modified Nordmøre grates with small bottom (7 to 12 mm bar spacing) and large upper panels, but there was excessive clogging on the lower portion. The best results (although still not conclusive) have been obtained with a tandem-mounted double grate system, where fish are sorted out by the first grid and the second grid sorts out small shrimp, with guiding panels and funnels in front of each. Grid angle was critical to avoid blockage, and water flow patterns within the sorting system affected performance. Certain size-selective grate systems yielded substantially higher economic returns. Plastic grates are used exclusively.

Research has been conducted to reduce finfish bycatch in the shrimp fishery. Without grates, the large offshore boats were getting about 15% finfish bycatch. Grates are now mandatory, and finfish bycatch has been reduced to 1% or less with respect to the shrimp landings. Bar spacings ranging from 22 to 28 mm all gave nearly the same results in terms of finfish bycatch reduction. Results were very good for cod, but redfish were problematic at all spacings. Selection ranges are much lower for roundfish than for flatfish. Twisting in the extension section can be a problem, once a twist is established it will not self-clear. A weight on the bottom and floats on the top will prevent such twists. Capelin bycatches can still be very troublesome, and even though cod bycatch rates are low, any cod bycatch at all is unacceptable when the stock levels are so depressed.

Experiments have been conducted on cod/flounder separation, trying to catch flounder while releasing cod. Experiments with horizontal bars at various installation angles and bar spacings gave good cod escapement, but too many flatfish were lost. Vertically-oriented bars mounted at 65 degrees and with 13 cm interbar spacing gave the best results, almost 90% cod escapement with little flatfish loss. Sort-X tests were performed but did not give good results perhaps because of very high catches of small cod affecting the configuration of the collection bag. A two-stage size sorting system is under consideration, using a grate to exclude the large cod, then a square mesh codend to release the small cod, retaining only the flatfish. There are also plans to test fish eyes and/or square mesh panels, installed behind a Nordmøre grid, to improve escapement of capelin and small redfish in shrimp trawls.

3.2.3. Great Lakes & British Columbia regions

1995 was the last year of a 3-yr program in the Great Lakes aimed at improving selectivity in the smelt fishery, with the goal of sorting out alewife, white perch, lake trout, and other finfish. The following approaches were tested: square mesh codends and extensions, square mesh codends alone, grids, plastic windows, and square mesh windows. Smelt losses with the grid were high, around 17%. This was rectified by putting a loose cover over the escape hole, but larger sprats were not released until the gear reached the surface.

A shrimp fishery is starting up in British Columbia, and oval grids are being evaluated for this fishery. Halibut bycatch in groundfish trawling is an emerging problem, and grids are under consideration.

Plastic grids are now commonly used in the inshore and offshore fisheries, and can be used in extreme temperatures.

3.3. Denmark

Denmark's grid research has all been in cooperative programs involving other countries, and these activities are described elsewhere in this report. DIFTA was the lead institution in an effort to develop a species-selective grid for industrial fish trawls, in partnership with the Marine Laboratory in Aberdeen. DIFTA has also participated in tests of size- and species-selective grids in shrimp trawls together with Norway, Sweden, Iceland, Greenland, and the Faroe Islands. Much of the flume tank work in these and other grid studies has been conducted in Denmark.

3.4. Finland

The size-selectivity of grids was evaluated in pelagic trawls used for Baltic herring, and a study was conducted in the lake fisheries for vendace. Results showed that flow manipulation in the sorting area was required in order to stimulate sufficient escape attempts, to prevent turbulence behind the sorting area, and to prevent the accumulation of fish pressed against the netting in front of the grid. The best configurations yielded good escapement levels and sharp selection curves, with no catch size effects, but it must be noted that very high catch rates were not experienced. Problems arose with handling the grids on the drums, and wear and tear on the polyamide netting near the grids was unacceptably high. Tests of escapee survival showed little benefit from grids relative to normal codend mesh selection, perhaps because the fish were already injured long before they arrived at the grid, which was just in front of the codend.

3.5. France

French fishermen asked IFREMER to develop a device for selective harvesting of monkfish. A study was initiated in 1993 involving flume tank tests and sea trials. Simply increasing codend mesh size was not an acceptable approach because this is a mixed-species fishery where hake, megrim, and skates are also harvested. After many sea trials, the best results were obtained with a grid where bars were mounted both vertically and horizontally, yielding rectangular grid openings measuring 55 mm high x 110 mm across. The following results were obtained:

a. monkfish: loss of 1% of marketable fish (weight), 55% shorter than 30 cm escaped
b. skates: no loss of marketable fish, 54% shorter than 40 cm escaped
c. hake: loss of 9% of marketable fish (weight), 54% shorter than 30 cm escaped
d. megrim: loss of 28% of marketable fish (weight), 67% shorter than cm escaped

Estimates of financial loss were 7% in the first year, no loss in the second year, and financial gain reached in the following four years. Sea trials on commercial vessels will be conducted in 1996.

3.6. Germany

There is no compulsory grid use in German fisheries, but some preliminary studies have been carried out, including involvement in cooperative research reported from the Netherlands and England. There are studies underway aimed at improving selectivity for Baltic cod. Square mesh and grids in codend windows have been tested. These included tests of a horizontal grid installed in the roof of the front half of the codend, 60 cm wide by 2 m long (4 x 50 cm sections), with bar spacings of 48 to 52 cm. Selectivity results with the square mesh top panels were about the same as those obtained with the grids. Grid costs are a very important negative consideration when it comes to adoption by the commercial fleet, as are modifications to gear-handling or other practices.

3.7. Greenland

The biggest problems are with undersized shrimp, juvenile redfish, and Greenland halibut, all taken in the shrimp fishery. Adult cod are not encountered on the shrimp grounds since the collapse of the cod stocks. Most of the grid work in Greenland was done in conjunction with Norway and has already been reported. With the best system tested, losses of marketable shrimp were too high, redfish bycatch reduction was substantial, but Greenland halibut did not appear to respond.

3.8. Iceland

3.8.1. Experience with shrimp grids on Icelandic vessels

Since June 1995 all Icelandic shrimp trawlers have been obliged to use shrimp grids on all offshore shrimping grounds, except a small area off the west coast where a fishery targeting both shrimp and fish takes place. The regulation became effective after numerous experiments on research vessels, including underwater observations. In June 1994 a sorting grid was tested onboard the shrimp trawler "Sunna" which tows two trawls simultaneously. The finding that the trawl with the grid caught 70% less small (10-15 cm) redfish with no loss of shrimp awoke the interest of the fishing industry. The regulation on the use of shrimp grids was made effective after many meetings and consultations with many people and organizations. All research results were presented in articles, during meetings, and as video programs. In spite of general interest many captains were very skeptical about using shrimp grids, but after grids were introduced few problems were encountered, and these were quickly resolved by telephone consultations or with the aid of technicians who made short trips by request on vessels experiencing problems.

Currently there are no longer any serious objections. Handling problems in rough weather were less than expected and no serious accidents have been reported. All involved have been favorably impressed with the improved shrimp quality, less sorting work, and reduced negative impact on the redfish, Greenland halibut, cod, and other important fish stocks. Reduction in bycatch, mainly Greenland halibut, has not been so important a factor as the shrimp prices, and shrimp catches have been very high.

The main difference between the Icelandic and Norwegian grids is that in Iceland the inter-bar distance is 22 mm versus 19 mm in Norway. Thus the shrimp loss in Iceland is minimal while selectivity for small fish should in theory be less effective. A second major difference is that Icelandic vessels have used bigger grids than is usual in Norway. This not only means a bigger grating area with less shrimp loss but also reduced likelihood of clogging by seaweed etc. Additionally there are some differences in construction details.

Shrimp grids are not obligatory in the inshore shrimp fishery where mainly 0-group gadoids are found, but no larger fish. Square mesh codends are more effective for releasing 0-group fish than are grids. On some few occasions larger (10-30 cm) fish have been found on the inshore shrimp grounds. When this occurs the use of grids is made obligatory on a short-term basis. Some initial problems with grids were encountered in this inshore fishery but these were also quickly resolved. There has been no serious discussion of requiring the small inshore shrimp boats to use grids at all times.

3.8.2. Experiments with Sort-X grids on Icelandic trawlers

Some experiments have been carried out in a cooperative project involving the Marine Research Institute, Jón Einar Marteinsson who joined such experiments in Norway, and some Icelandic skippers. The results have been very similar to those obtained in Norway. Following the fleet's favorable experiences with the shrimp grids, interest in Sort-X or similar grids is increasing. At least two vessels have tested the grids on their own initiative and some other companies are preparing experiments/use of grids.

Interest is probably highest in the redfish fishery where small fish are still caught and discarded in excessive quantities in spite of several area closures. Some skippers and/or vessel owners are also interested in using grids with very wide bar distances to release all small and medium-sized cod, retaining only the largest and highest-priced fish. Limited cod quotas are the basis of this interest. The Ministry of Fisheries has shown great interest in these experiments.

Discussion:
More details were requested on differences between the Icelandic and Norwegian grid designs. Icelandic grids tend to be larger and have a modification to the top to help prevent clogging. The most troublesome bycatch (discard) species is redfish, followed by Greenland halibut and small gadoids.

It was mentioned that Icelandic offshore shrimp boats combine the use of grids and square mesh codends, where knotted polyethylene, depth-stretched and heat-treated, is the codend material.

3.9. the Netherlands

Problems arise in pelagic fisheries when catches of Atlantic mackerel, horse-mackerel and herring are mixed. The species for which the quotum is fully fished is often discarded at sea. The SELMITRA project was aimed at improving the species and size selectivity of midwater trawls.

Studies were conducted on whether or not behavioural differences exist between the three species that can be utilized to separate them during trawling. Fish were caught alive and transported to laboratory tanks in Scotland where they were subjected to obstructions in their path in a raced swimming condition. From the first set of trials it was clear that contrast and orientation of the mesh barriers affected fish behaviour, and to some extent these species showed slightly differing patterns. An illusory block in the form of a black canvas funnel evoked strong avoidance and escape reactions through sections of netting placed in front of them. The fish showed the tendency to separate when swimming freely, but herded in a net they seek shelter in one mixed school.

Attempts were undertaken to locate schools at sea and find out whether these schools mix in their natural habitat, but no conclusive answer was found.

During the sea trials it was found that behaviour of fish differed when a cover was placed over the separation device. This cover could hamper fish passing through the device as escapees tended to accumulate in the forward part of the cover blocking the passage of new fish entering the net.

Model studies in the SEAFISH flume tank supported the design of selection devices. Sea trials were undertaken on RV "Solea" (three trips) and RV "Tridens" (four trips) from 1992 until 1995 to observe the reactions of fish to a variety of grid configurations, with and without a retainer bag or cover.

Variables under investigation were:
- cover design
- number and placement of grids
- grid bar spacing
- grid bar construction
- water flow inside the net

The trials also included a version of the black tunnel behind the selection panel or grid arrangement. When camera observations were possible these showed that fish were reluctant to enter the tunnel and attempted to pass out of the net walls or grid.

The best results in terms of species separation were obtained in December 1994 with grids set at an angle and flow deflectors installed underneath them, forcing the fish against the grids. In a few hauls Atlantic mackerel appeared in the cover and horse mackerel in the main codend. However the grid arrangement proved vulnerable in case of large catches and in the next sea trip ways were investigated to design an arrangement that would affect net geometry less and therefore be more acceptable to fishermen.

In the 1995 sea trials the grids were merely placed in the top panel and attempts were undertaken to herd the fish further upwards by flow manipulation and visual stimuli. This arrangement did not replicate the 1994 results in terms of species selection, as most fish appeared in the main codend in the catch comparison trials.

Many design alterations were tried out such as:
- an extended grid section
- grids with monofilament wires instead of metal bars
- flow deflectors in various positions
- two black tunnel sections instead of one
- herding ropes inside the tunnel of the net

Fish were observed swimming upwards, apparently guided upwards by these herding ropes. These were very easy to install and did not distort the net. A quantitative comparison between catches in a cover and in the main codend could not be carried out due to lack of time. It is therefore recommended to continue the research, as not all possible means to achieve the required species separation have been exhausted.

Discussion:
The Study Group had many questions and comments regarding the black canvas scaring sections. In this study, fish showed a strong reaction to the black section in the tank experiments, but it is unclear what effect it had at sea. In a similar Danish experiment cod showed no response to such stimuli, but it was noted that it seems to be very difficult to lead or frighten cod by any means.

It was mentioned that at the high towing speeds used for these tests (and typical for the Dutch pelagic fishery), small fish were simply not able to react to the grid in time to make successful escape attempts, which was the reason that the experimenters progressively increased the length of the grid section over the course of the experiments. Serious concerns were expressed over whether or not it is even feasible to build a grid system long enough to have a chance to work, especially at high catch rates. It was acknowledged that we are only beginning to understand the difficulties involved in size- and species-selectivity for pelagic fish.

It was pointed out that several innovative ideas were tested in the project. These included replacing the grids' bars with tensioned wires in order to reduce weight, and the herding ropes placed inside the tunnel of the net in order to scare fish upwards as an alternative to guiding panels. Flow deflectors were placed below the floor of the net in order to direct flows against the grids, and seemed to offer some success. None of these techniques received more than tentative trials and should be evaluated further.

3.10. Norway

3.10.1. A review of Norwegian research with grid sorting devices in towed fishing gears (full text found in Appendix III)

Abstract: The history of grids as selective devices in Norwegian fisheries dates back to 1989 when the Nordmøre grid was first introduced as a fish bycatch excluder in shrimp trawls. First tests of this grid to exclude fish bycatch (mainly cod and haddock) were carried out during the spring of 1989, and within approximately one year its use had been made mandatory in the coastal shrimp fisheries in northern Norway. This successful use of the Nordmøre grid to reduce finfish bycatch stimulated numerous research efforts in Norway to find applications of grid technology in other fisheries as well, mainly for the purposes of size selection. Grid devices to size select fish, shrimp, and Norway lobster have been developed and extensively tested. One such size-sorting system (the "Sort-X" grid) has given satisfactory results, both in terms of selectivity performance and compatibility with commercial fishing operations, while reducing the bycatch of undersized roundfish in the Barents Sea cod fisheries. It will be one of two grid devices (the other a Russian-developed system) whose use will be mandatory in those fisheries starting 1 January 1997. Other devices aimed at improving size-selectivity for shrimp or nephrops have given mixed results and work continues with the more promising approaches.

Discussion:
There was discussion of the feasibility of a floor-mounted size-selective grid for nephrops installed flat in the bottom of the sorting section, without any slope or guiding panel, and relying on gravity to release the nephrops. There was agreement that this might be an effective approach.

Some Study Group participants have observed distortions of the netting in front of the grids, especially with large catches, but this has not been seen in the Norwegian studies. However, all of the Norwegian ROV work has been done in shallow water where catches were small. Excessive wear & tear on the netting around the installation point of the grids' framework can be prevented by wrapping ropes around the frame after sewing it into the extension section, threading the ropes through the netting.

It was noted that in experiments on the survival of fish escaping through grids cod mortalities were nil and haddock escapee mortalities were very low.

3.10.2. The size-selective Sort-X grid system: construction, selectivity trials, & practical use

(full text found in Appendix IV)

The design and construction were based on practical experiments and underwater observations. Selectivity experiments have been made every season throughout 1990-95. Trials have been made on the following species: Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), redfish (*Sebastes* spp.), and Greenland halibut (*Reinhardtius hippoglossoides*). Relatively sharp size selection has been achieved for all the species tested. Size selectivity is very little affected by catch sizes and towing speeds. Trials on dense concentrations of fish show that size selection may be reduced. The top cover technique proves to work well during grid experiments. Since 1993 the Sort-X has been used by the cod fishing fleet. Acceptable size selection for cod and haddock has been achieved with 55 mm grid spacing combined with a 135 mm codend. By the end of 1995 over 100 cod boats were using it on a voluntary basis. In this fishery grids of 80 mm (front) and 55 mm (middle) are most often used. Many experiments have been conducted but few reports have been published. Grids optimized for cod (80 mm) retain virtually no haddock, saithe, or redfish. Saithe grids use 50 mm spacing with 100 mm codends, and selection curves are sharp and do not seem to be affected by high catch rates. Sort-X (50 mm) works well for redfish and Greenland halibut. Selection range for Greenland halibut is about 20 cm.

3.10.3. An experiment comparing the Sort-X with a Russian grid system

A single-grid system developed in Russia (the "Sort-V") was claimed to give results comparable to the Sort-X. This seemed to be generally confirmed by cooperative Russian/Norwegian comparative fishing experiments, at least so long as the Russian system was used in the Russian trawl. It did not function well when installed in the Norwegian Alfredo trawl. This may have been due to differences in the cover used on the two trawls; possibly the Norwegian cover may have distorted the Russian grid. When no covers were used on either trawl, catches from both trawls had exactly the same length-frequency distributions. Based on these results, starting in 1997 Russian boats must use the Sort-V in the Barents Sea, and Norwegian boats must use the Sort-X.

Discussion:
There was considerable interest in whether or not codend mesh selectivity suffers at higher catch rates, particularly since it seems that grid selectivity is less sensitive to catch size or catch rate. Research conducted in Norway, Germany and the US Alaska pollock fishery have all demonstrated a catch size effect, but other reports have given conflicting results. It was pointed out that grid selectivity processes and codend mesh selection processes are different and grids are typically installed well in front of the region where catch accumulates.

In view of the extensive research that has been conducted with the Sort-X grid, the Study Group expressed interest in seeing more of it published, and encouraged the use of broadly accepted statistical procedures. It was noted that the selection curves reported for the Sort-X feature shapes that differ from those seen with codend mesh selection, so this might be an appropriate application of the recently-developed "bootstrapping" statistical techniques.

It was mentioned that the selectivity experiments for Greenland halibut were conducted at depths ranging from 600 to 800 meters, and no depth effect on selectivity was seen although size composition did seem to vary by depth.

Considerable interest was expressed in the design and performance of the cover used in the Sort-X selectivity studies. The covers were heavily floated and were designed to be slack relative to the extension in order to allow them to open well vertically. Measured water outflow through the grid seemed to be heavy, helping to inflate the cover, and was the same whether or not the cover was in place. The cover netting was light green in color for low contrast. Finally, it was noted that the many floats on the cover that hold it away from the grid outlet may also pull the grid up and away from the floor of the trawl thereby compromising its sorting effect.

The Study Group requested more details on the materials and construction of the Sort-X grid system. The grids are made of solid stainless rod, and grid sections are hinged relative to each other in order to conveniently wrap onto a net drum.

Some additional remarks were made on inter-species differences. All flatfish species other than Greenland halibut seemed to escape almost completely. Observations showed that these other species turned and swam on their sides in the codend and grid regions and were thus oriented to pass easily between the bars of the grid. Numbers of small redfish in the experimental area were low.

3.10.4. Tests of a modified version of Nordmøre grid (paper, Appendix V)

A longer version of the Nordmøre grid was tested at lower angles of attack. Results showed that fish sorting was improved, especially for smaller redfish, and shrimp losses were reduced relative to a conventional Nordmøre grid. Guiding funnels were used with both grids. Various distances between the funnel outlet and the grid were evaluated, with no apparent effect. Escapees were collected in a cover. Various construction details to reduce shrimp blockage were also made. The angle of attack of the longer grid is more stable throughout the tow, unlike the standard grid which suffered decay in the angle as catch quantities increased towards the end of the tow. Water flow velocity through the elongated grid was also higher, and stayed high longer, demonstrating less blockage with shrimp, flatfish, and other material. At the lowest angle of attack, selectivity for cod and Greenland halibut was substantially better, but selectivity was only slightly better for redfish. As the angle of attack was increased towards the 45-48 degrees used with the standard grid, selectivity performance also approached the standard grid. Even with this improved performance, small fish bycatch levels were too high. There were other advantages: twisting was more-or-less eliminated, debris was shed better, shrimp loss was not so sensitive to slight variations in grid angle, and handling was actually easier during shooting and hauling. Instead of shrimp losses ranging from 3 to 9% as seen with the standard grid, they ranged from 2.5 to 6% with the longer grid at the lowest angle of attack.

Discussion:
It was noted that the tested towing speeds of 3+ knots seemed high relative to the 2 knots used in Canada, and that such high speeds might make it difficult for small fish to escape. However, these high speeds are typical for Norwegian shrimpers.

It was noted that the most extreme shrimp loss rates reported here, around 9%, are much higher than all previous experiments with standard Nordmøre grids, but this may have been due to the reduced angle of attack. Shrimp loss was not size-dependent because all the shrimp in the study area were small relative to the 19 mm bar spacing. The poor water flows recorded with the standard grid and the very high flows seen with the longer grid may have been illusory, that the sensor may be unreliable.

3.10.5. Tests of grids in Danish seines

Three small (70 cm x 70 cm) grid sections attached in tandem were installed in a Danish seine, installed sloping down from the roof with an upwards-sloping guiding panel following the grid. In another configuration an upwards-oriented deflector panel was installed to expose all of the fish to the grid and prevent free passage along the floor of the net, below the bottom edge of the grid. This deflector improved the L50 and reduced the selection range considerably for haddock, but similar improvements in performance for cod and saithe were less marked.

Large Danish seiners equipped with cranes had no difficulty handling the grids, but smaller, less well-equipped boats could not, so Isaksen tested square mesh codends in a trouser trawl experiment, evaluating 135 mm and 122 mm square mesh. Selection ranges for cod and haddock were about the same as those obtained with grids. Based on these results, Norwegian management authorities have requested that work continue evaluating square mesh for Danish seiners as an alternative to mandatory use of grids.

Discussion:
It was noted that similar experiments conducted in Denmark and Canada using trouser codends in Danish seines failed because the catch of large fish was always smaller in the small mesh codend, thus making it difficult to analyze the data according to conventional selectivity estimation procedures.

It was also pointed out that when Danish seines are used for flatfish (as they often are), grids will be a poor choice, which is one of the motivations for testing square mesh in the Norwegian Danish seine fishery.

3.11. Sweden

Experiments on size-selectivity for Norway lobster using sorting grids in the aft trawl belly (see paper in Appendix VI)

3.12. United Kingdom

3.12.1. Scotland

Since 1990 the main effort has been concentrated on completing a joint Scottish/Danish EU-supported project to develop a selective industrial fishing trawl for Norway pout in which the bycatch of protected human consumption species such as haddock, whiting, and herring could be significantly reduced. By dividing the gear into upper and lower compartments using a horizontal panel of netting it was hoped that the human consumption species would enter the upper part of the trawl while the pout, remaining close to the seabed, were taken in the lower compartment. When experimental work on FRV Clupea demonstrated that such an approach was unlikely to prove successful two other options were investigated on a chartered Danish commercial vessel. Both a 90 mm square mesh escape panel and a rigid metal grid with 20 mm spacing between bars were tried but neither of these methods produced useful results in separating the species. The project concluded that it was not possible to recommend further attempts to develop a species selective pout trawl and terminated in 1993.

Later selectivity experiments on FRV Clupea, using an improved design of the grid developed for the pout project, succeeded in releasing 79% of immature haddock and 91% of whiting. This design utilized 40 mm spacing between bars and was held at 45 degrees to the water flow by a lightweight metal frame. Such a device could not easily be used on a typical Scottish commercial fishing boat where the net is hauled by a net drum normally situated close to the stern so a simplified version was tried on a chartered vessel in 1994 but comparable results with roundfish were not achieved. Only 57% of haddock and 73% of whiting escaped through this grid which had longitudinal bars with a spacing of 40 mm in the upper two thirds and an open hole or vent in the lower part to which the codend was attached. The grid was set in to the after part of the extension piece at an angle of 30 degrees, which allowed it to be wrapped round the net drum without too much disruption to the hauling procedure. It was felt that several design improvements in plastic construction could be made but to date no further trials have been carried out. Cylindrical metal grids designed to facilitate the escape of immature prawns (*Nephrops norvegicus*) were also tested and a final analysis of the results is awaited.

3.12.2. England

A project was carried out with the aim of reducing finfish bycatch in the brown shrimp beam trawl fishery on the east coast of England. The first approach tested was a large-mesh veil net or sieve net installed within the trawl body, and leading to a fish escape vent. This worked fairly well for finfish with shrimp losses of 10% or less, except when weed & other debris blocked the meshes in which case shrimp losses were quite high. Early tests with grids installed within a cylindrical frame were promising, but the system was unacceptably expensive and cumbersome.

The next test was with a plastic grid (12 mm bar spacing) made out of plastic plumbing components. Whiting, plaice, and dab bycatches were reduced considerably with little shrimp loss. Buoyancy was critical, and blockage could cause problems. The findings of the experiment are presently under assessment with respect to making grid use mandatory. The fishermen are not enthusiastic, but they are beginning to recognize that some response to the finfish bycatch situation is inevitable.

3.13. United States of America

3.13.1. North Atlantic region

Tests with the Nordmøre grate were conducted in the U.S. North Atlantic shrimp fishery, with positive results: 85-90% reduction of protected finfish species and no detectable shrimp loss. The next year grid use was mandatory for part of the season, since 1993 its use has been made mandatory year-round. Industry was resistant at first but grids are now accepted. Grids are made of plastic and aluminium, with one-inch bar spacing. Carr pointed out that some fishermen also wish to retain some of the finfish and have been taking various steps to defeat the grids' function. Experiments carried out in Maine with 40 mm bar spacing showed that grids reduced regulated finfish bycatch by about 50%, but there are concerns about increasing density of these regulated species forcing adjustments of bycatch limits.

3.13.2. Pacific region

Grids are not mandated in any U.S. west coast fisheries. However, Nordmøre grids have been tested in the pink shrimp trawl fishery by the Oregon Department of Fish and Wildlife. Results were variable, but showed that grids were very sensitive to installation and rigging. Further work is planned.

3.14. Some highlights of grid research efforts in tropical and subtropical countries (Bjørnar Isaksen & C.W. West)

Australian shrimp fisheries suffer from problems with finfish bycatch, most strikingly in the estuarine fisheries. Nordmøre grids were tested in these fisheries with considerable success, and within a year most boats had adopted grids on a voluntary basis, and use is spreading.

Grids were also tested in Mozambique and Tanzania. The Nordmøre grid first tested suffered unacceptably high shrimp losses, especially the larger shrimp. A more successful approach used a horizontally-mounted grid in the top panel of the extension section combined with larger codend mesh sizes to reduce finfish bycatch.

A grid was tested, in comparison with a square mesh top panel, in the Indian deepwater shrimp trawl fishery. The goal was to release undersized and low-value finfish, while retaining all shrimp and marketable fish, and the twin-trawl experimental technique was employed. Some promising results were obtained with both approaches, although to date a configuration yielding commercially-acceptable results has not been identified. Since both approaches gave approximately the same results and the square mesh top panel was cheaper and easier to use, tests with the grid approach have been ended.

3.15. Chairman's summary of worldwide status of grid research:

There are three major examples of successful use of grids in commercial fisheries around the world: the Nordmøre grid for shrimp fisheries, the grids used in the Canadian silver hake fishery, and the Sort-X grids used in the Barents Sea groundfish fishery. Tests are underway around the world for other applications of grid technology: size selection for shrimp and nephrops, the brown shrimp fishery in England, and size selection for finfish in other regions and fisheries.

4. FURTHER APPLICATIONS OF GRID (GRATE) DEVICES (roundtable discussion)

The Study Group recognized that the Nordmøre grid is fairly successful, but still not perfect. Too many small fish, especially 0-group gadoids and redfish, are still not sorted out. Different sizes and mounting configurations have shown promise. Various materials have been tested and have advantages and disadvantages, including stainless steel, aluminium, composites, and sheet plastic.

It was pointed out that grids could be used in conjunction with other selectivity measures to target a specific size range of fish. For example, in species or populations where the very largest fish make a disproportionately high and valuable spawning contribution, grids could be used to release the largest fish while the codend mesh size could be fine-tuned to release small individuals.

Maintaining correct grid angle is a design issue, it may be possible to use ropes or other features to help stabilize desired angles unless the reduced angles are due to catch accumulation pulling down on the extension section. The Scanmar grid sensor provides active monitoring of angle and alerts the fishermen to the need to haul back.

Flow patterns have been identified as a sensitive issue. Flow disturbance in the grid area can be reduced by reducing the cross section of the bars by using tensioned wires, Kevlar-reinforced plastic bars of small diameter, or other novel constructions. Flow accelerators seem to have worked in some situations but other researchers have observed little benefit. Scoops have been used in grid trials in pelagic trawling to direct flow and have been found effective both from visual observations and selectivity results. From the conflicting results reported by various members of the Study Group it was acknowledged that flow manipulation is a tricky process. Clear flow that has been lost cannot be easily restored, so better strategies may be to locate components that require clear flow in areas that inherently have it, or to use low-drag materials and designs in critical areas.

Visual barriers (as an alternative to physical barriers such as funnels or guiding panels) have showed some potential for guiding fish but no definitive practical configuration has been developed.

Alternative grid shapes can be investigated, e.g. oval instead of rectangular frames, although to date the rectangular form remains the most accepted. Guiding funnels have been more popular than flappers, usually with a weight or twine or some other means to keep the funnel's roof from inflating upwards, or they can be made of square mesh.

Problems with blockage have been troublesome in developing size-sorting devices for shrimp. Since shrimp are passive, all such devices are essentially filters and for them to function the animals must be guided onto the filter and the filter must be kept clean. Bar shape seems to be important, the Canadians went from a squared-off profile to a rounded leading edge. Tests have been carried out in Norway with V-profile bars that orient the shrimp to the long axis of the openings, thus improving sorting and reducing blockage. There was speculation that grids could be made self-cleaning by allowing the bars to rotate or driving such rotation mechanically.

It was suggested that one possibility for nephrops trawling is to use a Nordmøre grid in a vertical trouser trawl to direct all fish into the upper codend where the mesh size could be optimized for fish. A second grid for nephrops size selection could also be employed. Such multi-stage or combination approaches could be attractive in other situations as well. Grids can be used in fixed gears such as fyke nets for eel and lobster. A grid has been used to exclude salmon in a midwater pair trawl targeting squid.

It was noted that size separation results tend to be fairly consistent among tows within a single experiment, but are less consistent across experiments. Most participants felt that differences in the characteristics of the populations sampled are probably responsible for such differences in results rather than some fundamental property of grid selection processes. However, some participants did not agree with the assertion of varying results, that according to their experience selectivity results do tend to be consistent between experiments.

5. ADVANTAGES AND DISADVANTAGES OF GRIDS COMPARED TO OTHER DEVICES (roundtable discussion)

The Study Group acknowledged that there have been relatively few experiments directly comparing grids with other techniques. Planned and ongoing Baltic cod research will feature such comparisons. Some data from experiments conducted in the Barents Sea could permit limited comparisons of selectivity parameters estimated for normal and square mesh codends, diamond-mesh codends with shortened lastridge ropes, and grids. In Canada there has also been a great deal of selectivity work done, and while it does not feature direct comparisons the calculated selectivity parameters can be compared and evaluated. It was noted that most selectivity research has been done with the covered codend technique, with necessarily limited catch sizes, so it may be hard to compare to commercial practice.

In studies done to date the selectivity properties of grids do not seem to be substantially affected by catch rate or catch size, perhaps because the selectivity process with grids takes place in front of the codend. The selection range for cod and haddock seems to be about 8 - 10 cm, independent of catch size, towing speed, and other factors. In Canada the same selection ranges have been achieved with square mesh, although at rather low catch rates and catch sizes. Similar studies in Iceland showed that L50's fell and SR's increased at high catch rates. For Alaskan pollock, results clearly showed that L50's in square mesh and diamond codends fell with increases in catch size due to blockage of the codend meshes.

Grids offer the opportunity to achieve good selectivity while still using relatively small codend mesh sizes, and it may be harder to "cheat" and manipulate grid selectivity. At the same time, switching grid spacing facilitates selectivity fine-tuning.

It was noted that we cannot realistically begin to compare advantages and disadvantages until the scattered data on different techniques have been assembled and compiled for thorough comparison.

Do grids offer any survival advantage? Norwegian and Finnish studies do not demonstrate any significant benefits, but for different reasons. In the Norwegian study cod and haddock suffered little or no mortality regardless of technique, in Finland nearly all the small herring died no matter what device was tested. The Study Group agreed that survival is heavily species-dependent, that none of the current escapee survival data permit a definitive answer since no survival studies have ever been conducted at normal commercial catch rates, catch sizes, or tow durations. Grids could be placed further forward in the trawl to improve survival by reducing the fish's exposure to stress and injuries suffered as they pass down the trawl.

What about practical considerations, objections from fishermen? Many participants have noticed that typically objections are intense until the grids actually enter use, but after a brief period of use the objections vanish. The Canadian all-plastic grates are quite easy to use, and the fishermen appreciate the reduced need to sort their catches. Nordmøre grids are commonly wound onto the drum, but only after the codends have been dumped. Stability can be an issue, and in some circumstances special measures must be taken to prevent twisting. Fouling remains a threat.

6. RECOMMENDATIONS

Participants recommended that the Study Group:

1) ***compile grid and non-grid selectivity parameters and relevant associated data for finfish and shellfish***. Such additional information would be used to facilitate interpretation of the results and could include light intensity, catch size, towing speed, experimental and analytical methods employed, etc. The Chair will take the responsibility of preparing and distributing a questionnaire, then collecting and collating the responses.

2) This information should include an accounting of ***how many vessels in the various countries are actually using grids***. Informal estimates by Study Group participants came up with a total of over one thousand commercial vessels worldwide that are presently using grids.

3) ***Estimate the impact of actual and potential grid usage on discard levels for non-target species in the various fisheries concerned***. Such information could be made available to assessment biologists and other interested parties who could in turn estimate the impact on the biological status of the affected stocks.

4) ***Participants were asked to send in their own bibliographies in order to compile a comprehensive bibliography on grids, including gray literature***. This could form the foundation for an annotated bibliography.

5) It was suggested that the ***Study Group work on the above items by correspondence and meet again in two years***.

APPENDIX I

List of Participants

Appendix I. List of Participants

Belgium	Mr. Hans Polet	Fisheries Research Station, Ostende
Canada	Dr. Steve Walsh	Dept. Fisheries & Oceans Canada, St. John's
	Mr. Gerald Brothers	Dept. Fisheries & Oceans Canada, St. John's
	Mr. Chris Cooper	Dept. Fisheries & Oceans Canada, Halifax
	Mr. Alain Fréchet	Dept. Fisheries & Oceans Canada, Mont-Joli
	Mr. David Tait	Scantec Ltd., Dartmouth
Denmark	Mr. Thomas Moth-Poulsen	DIFTA, Hirtshals
Finland	Dr. Petri Suuronen	Finnish Game and Fish. Res. Inst., Helsinki
France	Mr. Gérard Bavouzet	IFREMER, Lorient
Germany	Mr. Erdmann Dahm	Institute for Fishing Technology, Hamburg
Greenland	Mr. Jesper Boye	Grønlands Naturinstitut, Copenhagen
Iceland	Mr. Gudni Thorsteinsson	Marine Research Institute, Reykjavik
Netherlands	Mr. Bob van Marlen	RIVO, IJmuiden
Norway	Mr. John W. Valdemarsen (*chairman*)	Institute of Marine Research, Bergen
	Mr. Charles W. West (*rapporteur*)	Institute of Marine Research, Bergen
	Mr. Bjørnar Isaksen	Institute of Marine Research, Bergen
	Mr. Roger B. Larsen	Norwegian College of Fishery Science, Tromsø
Sweden	Mr. Hans G. Andersson	National Board of Fisheries, Göteborg
	Mr. P.-O. Larsson	Institute of Marine Research, Lysekil
	Mr. Mats Ulmestrand	Institute of Marine Research, Lysekil
U. K.	Mr. Derek Galbraith	SOAFD Marine Laboratory, Aberdeen
	Dr. Norman Graham	University of Humberside, Grimsby
U. S. A.	Mr. William H. Amaru	New England Fish. Mgmt. Coun., Orleans, MA
	Mr. Chuck Byrne	NMFS, Woods Hole, MA
	Mr. H. Arnold Carr	Mass. Div. Marine Fisheries, W. Sandwich, MA
	Mr. Daniel Erickson	University of Washington, Seattle, WA
	Mr. Antonio Perez-Comas	University of Washington, Seattle, WA
	Mr. John Kenney	NMFS, Narragansett, RI

It was noted that several countries or groups with significant experience in grid research were invited to attend this meeting but could not send participants: Australia, Russia, and the U.S. Gulf of Mexico region.

APPENDIX II

Brothers G. and Boulos, D.
Size sorting shrimp with an in-trawl grid system.

ICES, FTFB WORKING GROUP MEETING
WOODS HOLE, USA APRIL 15 - 18, 1996

SIZE SORTING SHRIMP WITH AN IN-TRAWL GRID SYSTEM

BY

G. BROTHERS & D. BOULOS
DEPARTMENT OF FISHERIES & OCEANS
P.O. BOX 5667
ST. JOHN'S, NEWFOUNDLAND
CANADA, A1C 5X1

ABSTRACT

Between September 16 and November 3, 1995, thirty, 13 to 20 meter vessels were selected to investigate the effectiveness of an in-trawl grid sorting system to reduce the catch of small shrimp. Each vessel was given a quota of 8,300 kg of shrimp to harvest in NAFO Sub-Division 4R. The vessels were divided into five groups of six vessels and only one group operated at a time. Four vessels in each group used size sorting grids with either an 8mm or 10mm bar spacing that were installed in shrimp trawls behind the Nordmore grids, while the two remaining vessels operated as controls and only used Nordmore grids. Both the size sorting and Nordmore grids were constructed from plastic with dimensions that were either .67 or 1 meter wide by 1.3 meters long. Underwater observations were obtained with a fixed Simrad-Osprey colour camera system. It was observed that water flow through the grid bar spacings was reduced and often created a blockage of shrimp in front of the grid. However, results indicated that the vessels which used size sorting grids with a 10mm bar spacing caught 9% more large shrimp than vessels operating without size sorting grids. Vessels with these grids also averaged $0.09/lb. more for their catch. There was no significant loss of catch.

INTRODUCTION

In the northern Gulf of St. Lawrence, approximately 2% of the landed quota consisted of under-sized shrimp (2g and under) in 1994. This increased to 10% in 1995 and some vessels landed in excess of 25% (Pers. Comm.). These under-sized shrimp have no economic value and are actually subtracted from the allotted quota. The landed value for a catch is determined by both its size and percentage of large shrimp (6g and larger). Catches with a higher percentage of large shrimp fall into a higher price grouping and are more valuable (Figure 1). The value received for a catch can be increased by improving the selectivity of a shrimp trawl. Not only would a more selective shrimp trawl increase the economic return from the resource, but it would also give the less valuable small (2g to 6g) and under-sized shrimp an opportunity to remain in the ocean and grow.

There have been a number of attempts to improve the size selectivity of shrimp trawls. Square mesh codends have been studied in the Scotia Fundy Region (Cooper, 1993), the northern shrimp fishery off Newfoundland (Hickey et al., 1993) as well as the fisheries in Iceland (Thorsteinsson, 1992) and Greenland (Lehman et al., 1993). For most of these studies, square mesh codends produced some reduction in the amount of small shrimp caught. However, in some cases, problems such as increased shrimp breakage and a loss of larger shrimp were encountered. Increases in the diamond mesh size (Tait and Tait, 1993) and the use of shortened lastridge ropes (Boudreau, 1993) were also evaluated in the northern shrimp fishery and have also proven not to be very effective at reducing the catch of small and under-sized shrimp.

Underwater video observations have indicated that shrimp, unlike finfish, do not actively attempt to escape through codend meshes (Pers. Obs.). This indicates that a device, such as a grid, which imposes a selection mechanism in the shrimp's path could be more effective in reducing the catch of smaller shrimp.

The ability of size sorting grids to reduce the percentage of small and under-sized shrimp have been studied in the Norwegian fishery (Valdemarsen, 1993) and both the northern shrimp (Boudreau, 1993) and the northern Gulf shrimp (Brothers, 1995) fisheries. Results from the recent study in the northern Gulf shrimp fishery were very encouraging and indicated that a grid system, installed behind the Nordmore grid, within a shrimp trawl could improve the size composition of a shrimp catch without any significant reduction in the catch rate. To further evaluate these results, the Fish Harvesters' Resource Centres, with funding provided by the Canada/Newfoundland Cooperation Agreement for Fishing Industry Development (CAFID), conducted another shrimp size selectivity study. A 250mt shrimp quota was allocated and 30 vessels were permitted to participate in the study. The main objective of this study was to further test the effectiveness of the size sorting grid, as used in Brothers (1995), and in particular, to evaluate size sorting grids with an 8 or 10mm bar spacing.

MATERIALS AND METHODS

Experiments with shrimp size sorting grids were conducted from September 16 to November 3, 1995 in the northern Gulf of St. Lawrence (NAFO Division 4R). Thirty shrimp vessels were selected to participate in the project; 29 from Newfoundland and one from Quebec. The vessels were chosen from a random draw and included a size range from 13 to 20 meters. Twenty-five of the vessels used a model 1168 shrimp trawl, four used a model 1000 trawl and one used a model 1340 trawl. All used a nominal 40mm mesh size codends and fished in water depths ranging from 250 to 300 meters.

The 30 vessels were divided into five groups of six with each group fishing for a maximum of 5 days or until their individual quota of 8,300 kgs. was caught. Within each group, four vessels used a shrimp size sorting grid which was located behind the Nordmore grid, while the remaining two were used as controls and only used a Nordmore Grid. Vessels which used a large Nordmore grid (1.3m x 1m) containing a bar spacing of 25mm, also used a large size sorting grid while vessels which used a smaller Nordmore grid (1.3 x .67m) with a bar spacing of 19mm used a small size sorting grid (Figure 2). Two different bar spacings, 8mm or 10mm, were evaluated with the size sorting grids. Prior to fishing with the last group of vessels, the small grid with an 8mm bar spacing was lost and a large grid with a 7mm bar spacing was substituted. Both the Nordmore grids and sorting grids were made of plastic.

The shrimp size sorting system (Figure 3) consisted of a rigid grid with the same dimensions as the Nordmore grid. While the Nordmore grid was installed at a 48° angle, the size sorting grid was installed at a 33° angle. Both were installed into a section of 40mm mesh netting, 368 meshes on-the-rounds and 200 meshes deep. A 6mm mesh guiding panel was placed in front of the sorting grid to guide all the shrimp passing through the Nordmore grid down to the bottom of the size sorting grid. In theory, the large shrimp move up the sorting grid, pass through a rectangular opening 25cm x 1m (large grid) or 25cm x .67m (small grid) in the top of the grid and move back into the codend. The small and under-sized shrimp should pass through the sorting grid and are deflected out of the trawl through an opening in its bottom. A 6mm mesh panel is installed behind the sorting grid to deflect shrimp out of the trawl.

Monitors onboard each vessel collected set and catch data while the total catch weight, percentage by weight for large, small, and under-size shrimp were obtained from the dockside buyer.

A gear technologist made periodic trips to oversee the data collection and to conduct underwater observations with a fixed simrad-osprey colour camera system. Much of this footage was used to produce an information video on the project.

The sampling data obtained from each vessel was categorized to reflect either the catch rate, the catch composition or the catch value. The catch rate (catch(kg/hr) was determined from the total shrimp landed for a trip and the duration (hours) of all fishing sets. Percentage of large shrimp in the catch was determined from dockside sampling. The catch value was summarized by the catch $/hour and the catch's $/pound landed.

A number of invalid sets were omitted from each of the comparisons and the landed catch data was adjusted accordingly. Sets were considered invalid when gear damage was recorded or when either the Nordmore grid or the sorting grid systems were found to be completely blocked.

The statistical analyses that were performed on this data took on a two stage approach. First, the results with the different riggings were compared while controlling for potential group differences and second, the different riggings were compared for each of the five groups of vessels individually. The initial comparison was conducted by way of an unbalanced randomized block design (Montgomery, 1991). The secondary comparison was conducted using a one-way analysis of variance for each group of vessels. Bonferroni's procedure (Montgomery, 1991) was used to conduct pairwise comparisons among the six different riggings tested and among the different groups. An alpha level of 0.05 was used to indicate a statistically significant difference for all tests.

RESULTS

Catch Rates

The average catch rates for the different riggings were fairly consistent, ranging from 143 to 171 kg/hr for most and 117 kg/hr for the grid with a 7mm bar spacing (Figure 4 and Table 1). This grid was only used with the last group of vessels and it was noted that the catch rate was low for all riggings used by this group of vessels. The catch rate did not differ significantly among the various riggings but a statistically significant difference was found among the different vessel groups. Comparing the different vessel groups (Figure 5), it can be seen that the catch rate decreased with the later groups. Pairwise comparisons indicated that the first, second and third groups of vessels resulted in significantly higher shrimp catch rates than was obtained by either the fourth or fifth groups. Moreover, the later groups coincided with dates later in the fall and this indicates that shrimp became less available as the fall season progressed.

When each vessel group was assessed individually, a statistically significant difference was obtained for the various riggings used with only the last group (Figure 6). A comparison of the rigging used with the fifth group indicated that usage of the small grid with a 10mm bar spacing resulted in a lower shrimp catch rate than was obtained when using the large grids with either an 8mm or 10mm bar spacing. This vessel was the only one in the group to still use a guiding panel in front of the sorting grid but there was too little data to make any attribution to the presence of the panel.

Catch Composition

The average percentage of large shrimp obtained by the vessels was found to range from 45.5% to 57.8% with the different riggings (Figure 7 and Table 2). The large grid with a 10mm bar spacing resulted in the highest percentage of large shrimp, 57.8%. This percentage was significantly higher than either the standard rigging, 48.9%, or the small grid with an 8mm bar spacing, 45.5%. The different vessel groups did not differ much with respect to the percentage of large shrimp caught (Figure 8); the first group caught the lowest percentage of large shrimp and this percentage increased progressively with the later vessel groups. The slight increase in the percentage of large shrimp obtained with later vessel groups appears to be a result of the lower catch rates encountered. Lower shrimp catch rates may reduce the possibility of grate blockage and improve the selection process.

The percentage of large shrimp caught when using the different riggings was a little variable across the vessel groups (Figure 9). The grid with a 10mm bar spacing resulted in the highest percentage for all but the first vessel group. The high variability associated with the different vessels was believed to have influenced the results to the extent that these percentages were identified as statistically significant for only the fourth vessel group.

Catch Value

The shrimp $/hour ranged from $163.61/hr when using the large grid with a 7mm bar spacing to $224.00/hr and $215.68/hr when using the large grids with either an 8mm or 10mm bar spacing, respectively (Figure 10 and Table 3). The grid with a 7mm bar spacing was only used with the last group of vessels which had the lowest catch rates. The value/hour did not differ significantly among the various riggings, however, there was a significant difference among the vessel groups. Although not significant, these differences for the riggings give some indication that the larger grids tend to result in a higher shrimp value/hour. Comparing the vessel groups (Figure 11), it appears that the value/hour decreased with the later groups, much like the decrease noted with the catch rate.

The shrimp $/lb was found to differ significantly with the various riggings used. The large grid containing a 10mm bar spacing resulted in catches with the highest value/lb (66¢/lb) and this was significantly higher than what was obtained when using either the standard rigging (57¢/lb) or the small grid with an 8mm bar spacing (54¢/lb) (Figure 12). The shrimp $/lb was similar across groups, however, the first group did produce the lowest $/lb (Figure 13). These results indicate that usage of larger grids resulted in catches that were more valuable for the fishing effort and more valuable for the weight landed.

The value obtained for an hour of fishing was usually higher when using one of the large grids (Figure 14 and Table 4). However, these differences were only significant for the last group of vessels. The fifth vessel group indicated that usage of the small grid with a 10mm bar spacing resulted in a significantly lower catch value/hour than was obtained with the large grid of the same bar spacing. This difference was such that $118.06/hr was obtained when using the small grid as opposed to $181.25/hr with the large grid.

The value/lb for the landed catch was found to always be greater for the larger grids that were used with each group of vessels (Figure 15). However, the differences were determined not to be statistically significant for any of the vessel groups when compared individually. These differences were marginally nonsignificant for the third and fourth groups of vessels, both of which resulted in an 18¢/lb difference between the best and worst performers; the best rigging in both being the large grid containing a 10mm bar spacing.

These results indicate that the 10mm bar spacing larger grids resulted in a more valuable catch in both the value obtained for each hour fishing and the $/lb. This grate resulted in an average value that ranged from 1 to 18¢/lb more than the standard rigging.

DISCUSSION

The results have indicated that the catching efficiency was relatively consistent when using any of the riggings that were tested. The efficiency did decease as the fall season progressed. The large grid with a 7mm bar spacing, which was only used with the last group of vessels, resulted in a low catch rate. This indicates that the loss of small shrimp was not sufficient to impact on the catching efficiency.

The catch composition was found to change depending on the rigging used. Larger grids consistently caught the highest percentage of large shrimp. The large grid with a 10mm bar spacing landed an average of 9% more large shrimp than the standard rigging.

The catch $/lb and the $/hr were found to always be highest when one of the large grids were used. The large grid with a 10mm bar spacing averaged $26.92/hr more and 9¢/lb more than was obtained with the standard rigging. The 1995 landed catch consisted of 10% under-sized shrimp (Pers. Comm.). If the landed shrimp catch (8.1 million pounds) contained 9% more large shrimp, the value for this landing would have risen by over $600,000, corresponding to an 12% increase in revenue.

These findings compare favourably to a preliminary sorting grid experiment that was conducted during the summer of 1995. This study compared the catching efficiency, composition and value of an 18m shrimp vessel fitted with a sorting grid containing a 7mm bar spacing to other vessels that fished the same area and time. The results indicated that the grid produced an average of over 9% more large shrimp by weight. This was also reflected in the value as $32/hr more revenue was obtained when the sorting grid was used. Furthermore, the only nonsignificant difference resulted from a comparison of the catch rate. This latter point supports our findings that the increased loss of small shrimp associated with these shrimp size sorting grids did not significantly impact on the overall catch rate.

REFERENCES

Boudreau, M. 1993. Industrial Shrimp By-catch Selectivity Experiment. 1993 Shrimp Selectivity Workshop, St. John's, Newfoundland, July 6-7.

Brothers, G. 1995. Reducing the Catch of Small Shrimp with a Size Sorting Grate. Industry Development Division, CAFID Project Summary No. 6, 4p.

Cooper, C. 1993. Shrimp Trawl Demonstration Project with Square Mesh Cod-ends. Industry Services and Native Fisheries, Scotia Fundy Region, Halifax, Nova Scotia, Project Summary No. 39, 4p.

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

Lehman, K., J.W. Valdemarsen, and F. Riget. 1993. Selectivity in Shrimp Trawl Codends tested in a fishery in Greenland. ICES mar. Sci. Symp., 196: 80-85.

Montgomery. D.L., 1991. Design and Analysis of Experiments. 3rd. edn. John Wiley and Sons, New York.

Thorsteinsson, G. 1992. The Use of Square Mesh Codends in the Icelandic Shrimp (Pandalus borealis) fishery. Fish. Res. 13:255-266.

Tait, D. and W. Tail. 1993. Codend mesh experiment conducted on the M/V " Northern Osprey", Shrimp Selectivity Workshop, St. John's, Newfoundland, July 6-7.

Valdemarsen, J.W. 1993. Selective shrimp trawling using grid devices. Shrimp Selectivity Workshop, St. John's, Newfoundland, July 6-7.

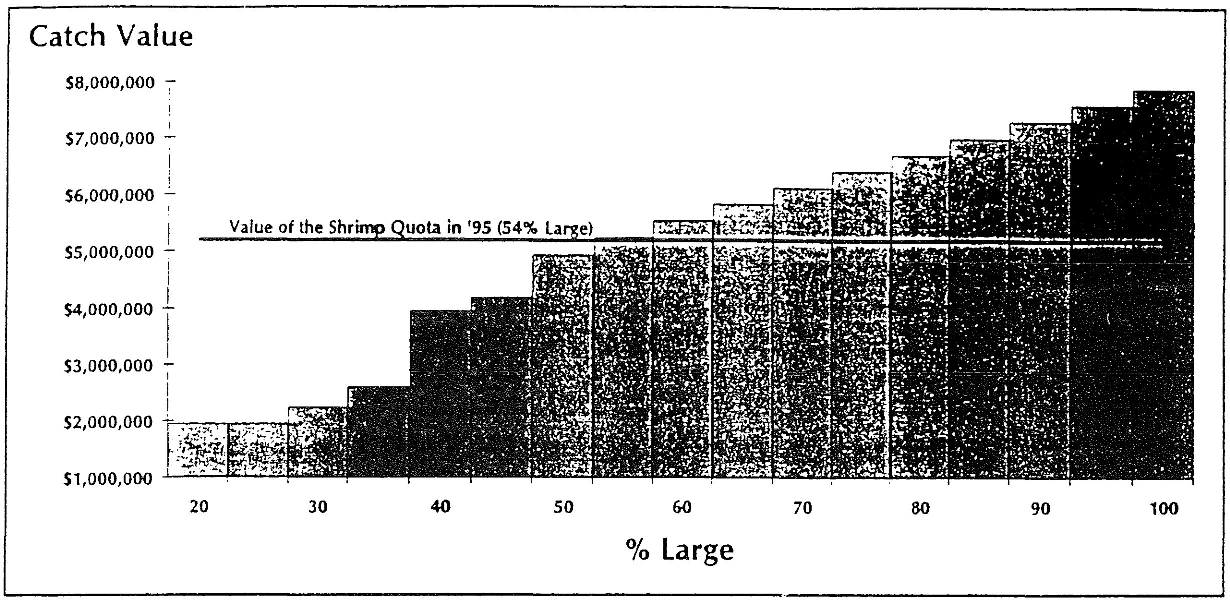


Figure 1: A Comparison of the Value Obtained for the Shrimp Quota in 1995 ($5.1 million) and the Potential Value with Differing Percentages of Large Shrimp.

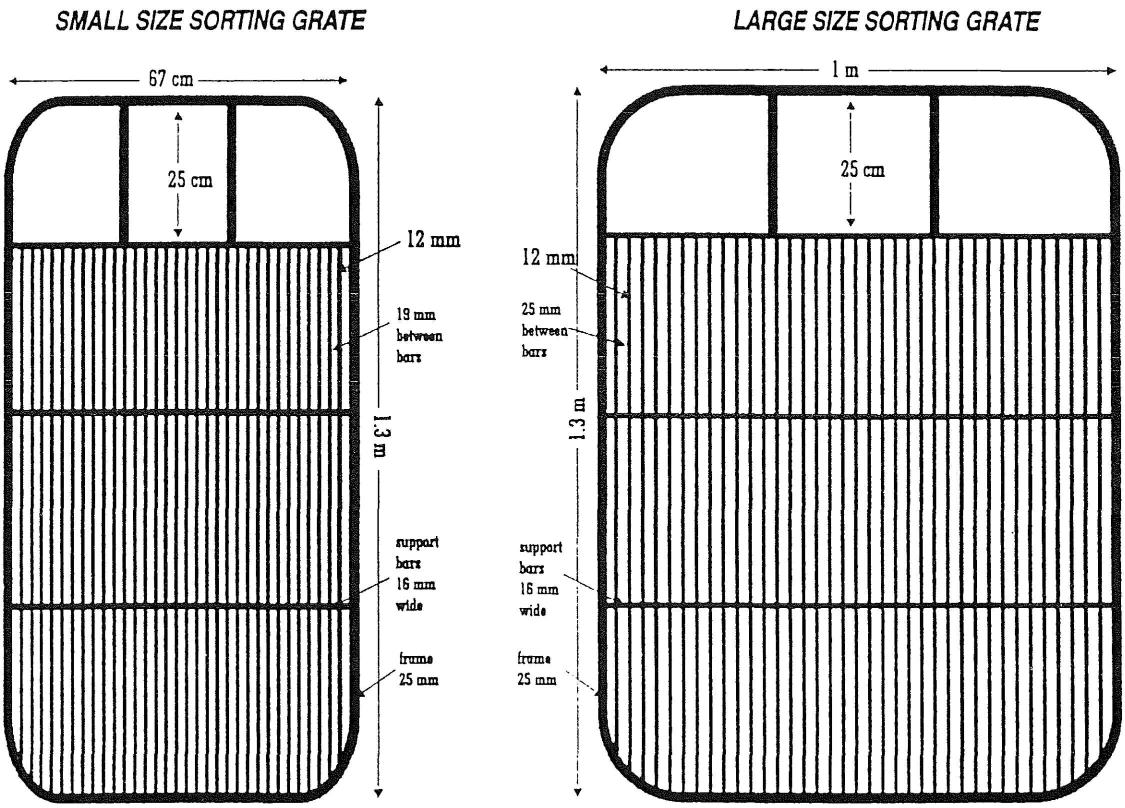


Figure 2: A Diagram of the Large and Small Shrimp Size Sorting Grates.

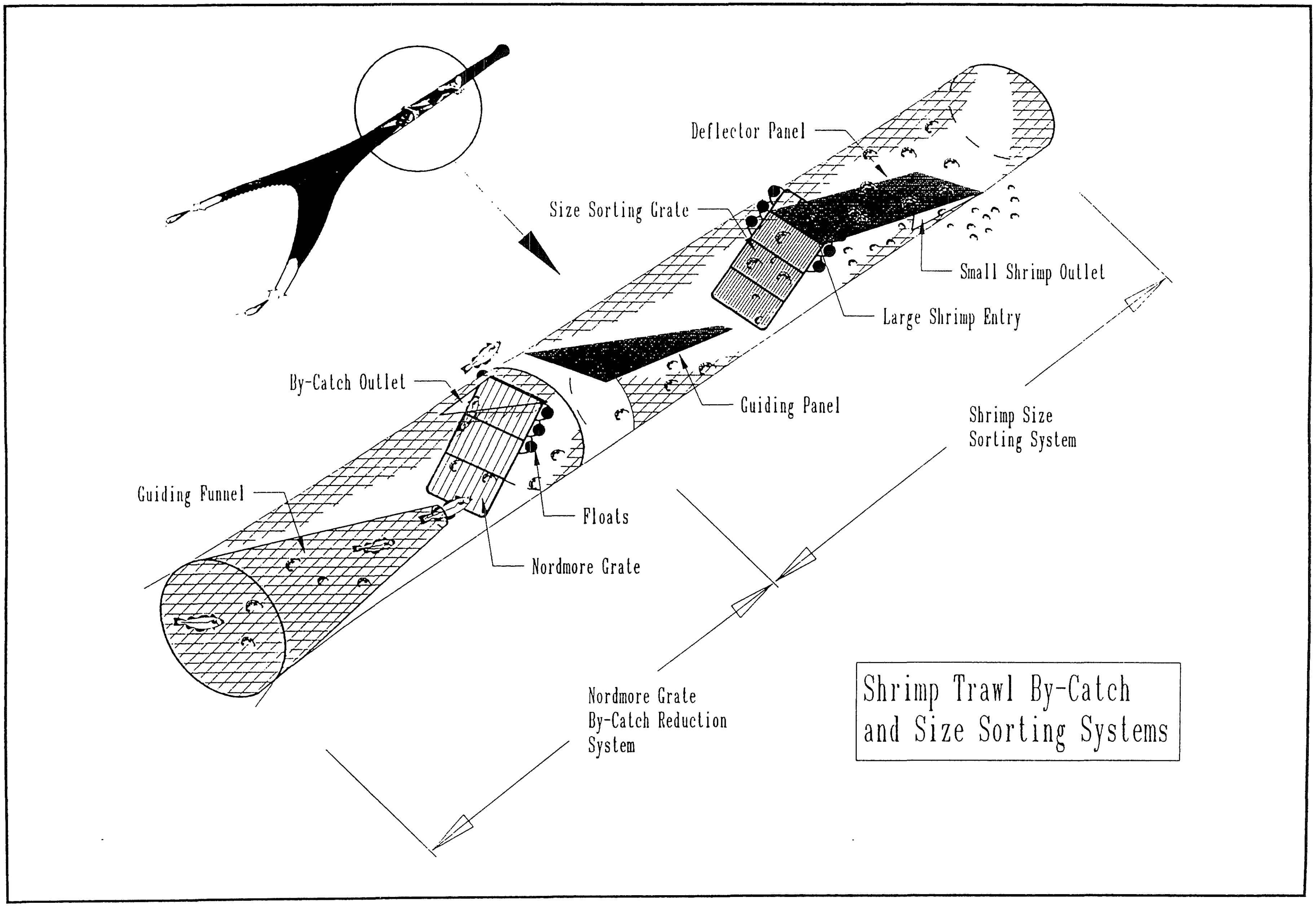


Figure 3: A Diagrammatic Representation of the Size Sorting Grate and its Mechanics.

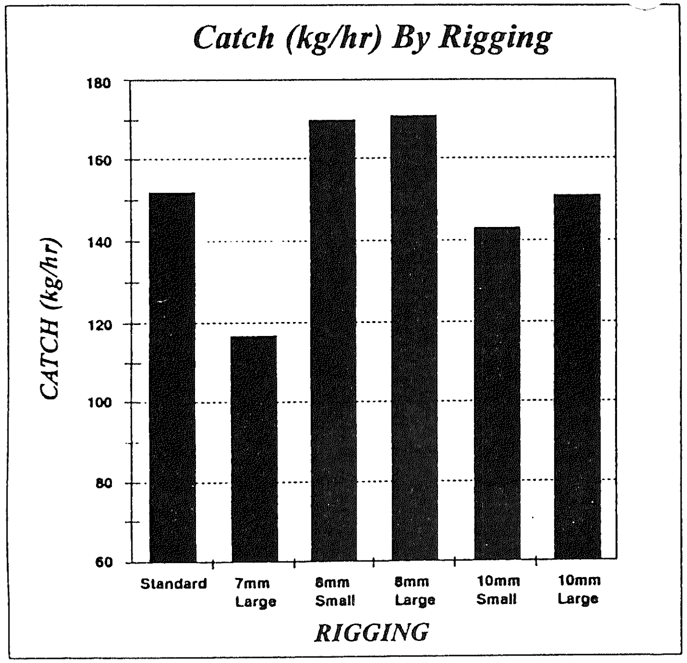


Figure 4: A comparison of the catch rates obtained with the various riggings.

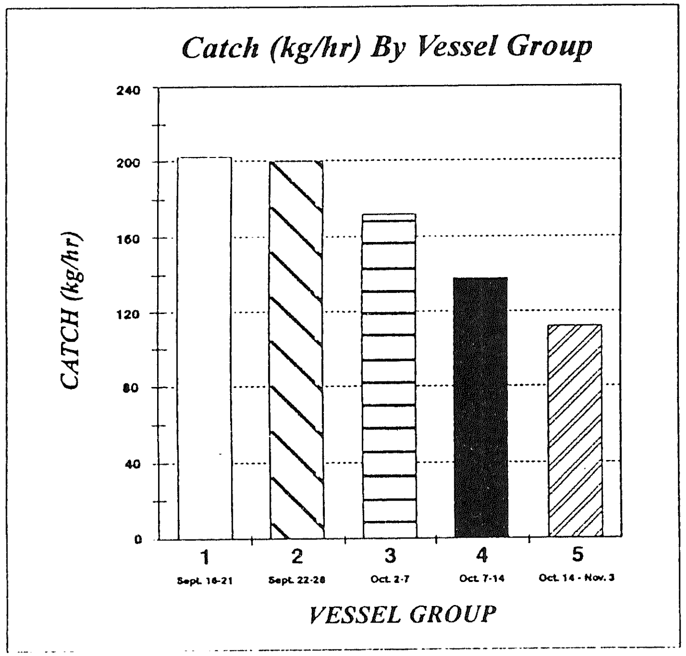
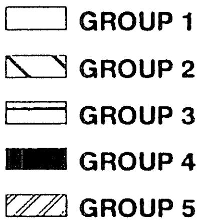


Figure 5: Catch rate comparisons for the five vessel groups.



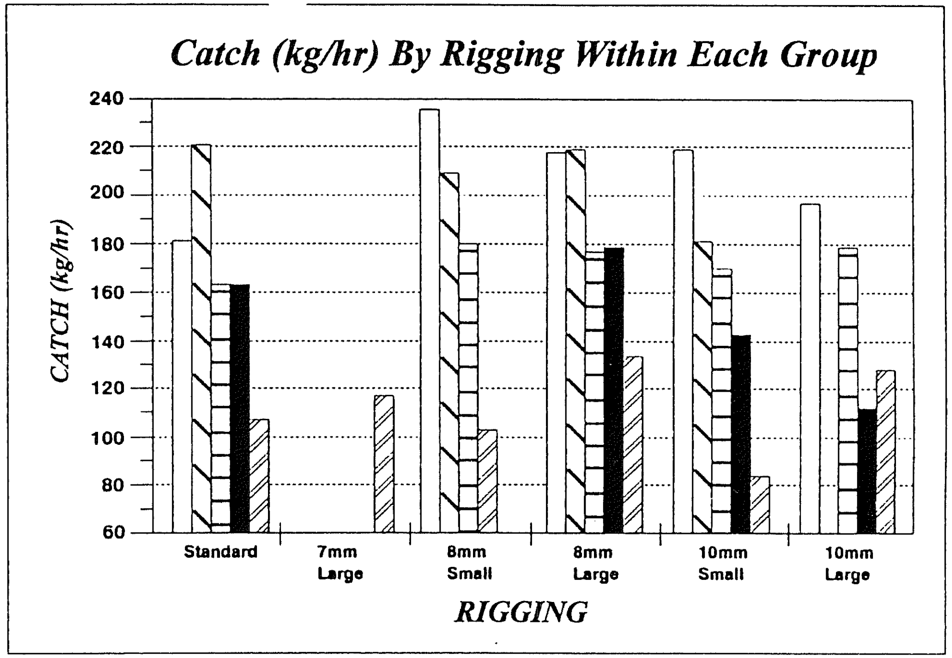


Figure 6: A comparison of the shrimp catch rates obtained when using the various riggings within each vessel group.

	CATCH RATE (KG/HR) BY VESSEL GROUP					
RIGGING	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	AVERAGE
Standard	181	221	163	163	107	152
7mm Large*	-	-	-	-	117	117
8mm Small**	236	209	180	103	-	170
8mm Large	218	219	177	179	134	171
10mm Small	219	181	170	143	84	143
10mm Large	197	170	179	112	128	151
AVE./HR	203	200	172	138	112	

* This grate was only used with the last group of vessels, when the catch rates were lowest.
** This grate was lost during tests within the fourth group of vessels.

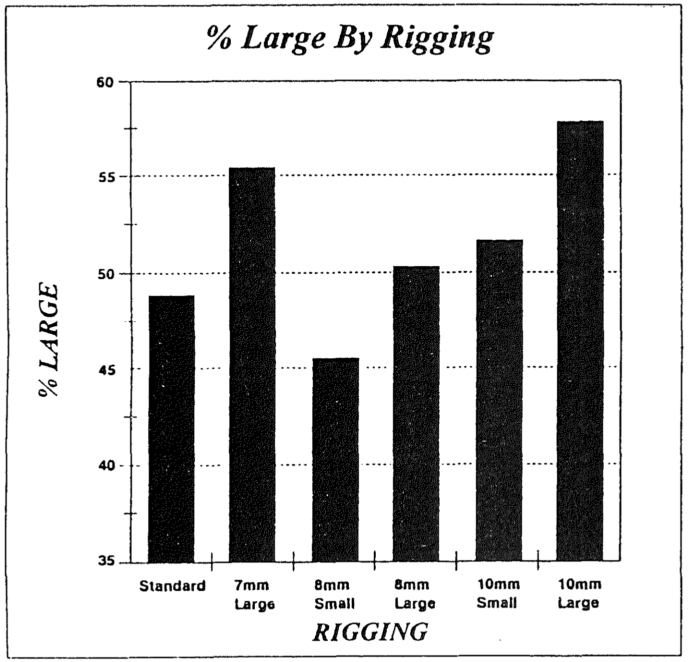


Figure 7: A comparison of the percentage of large shrimp (by weight) caught when using the various riggings.

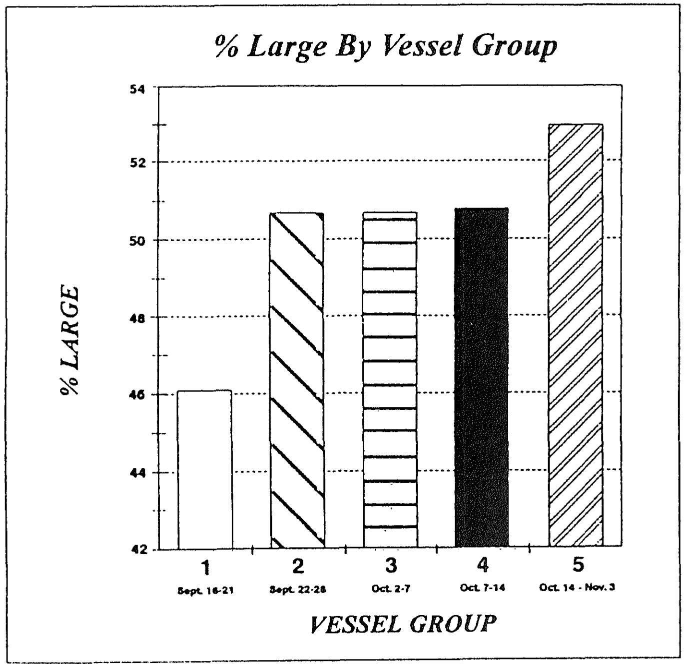
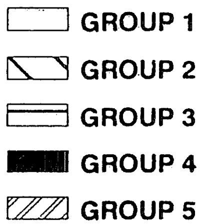


Figure 8: A comparison of the percentage of large shrimp (by weight)



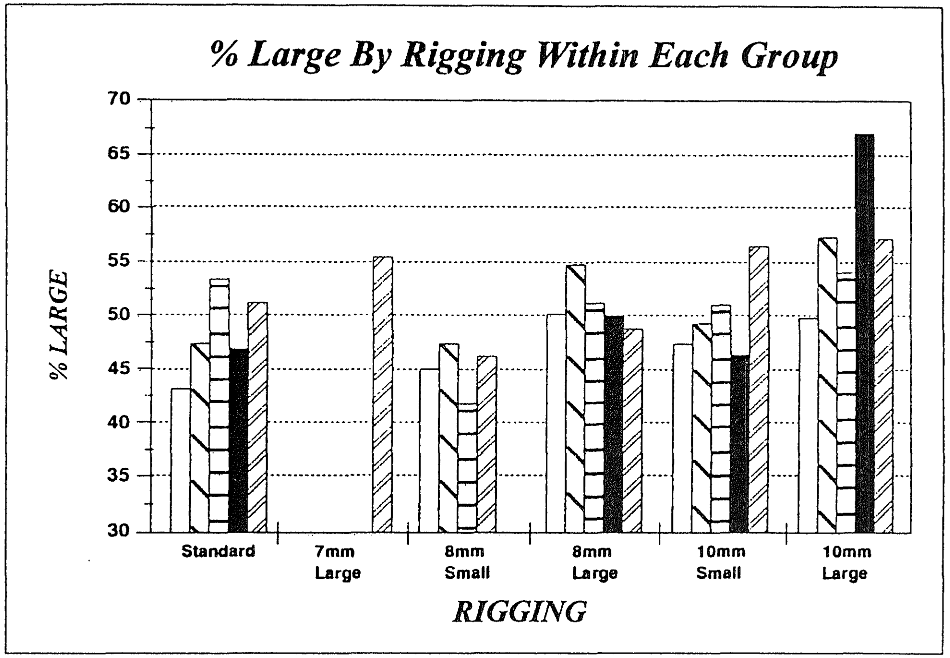


Figure 9: A comparison of the percentage of large shrimp (by weight) caught when using the various riggings within each group of vessels.

	% LARGE SHRIMP LANDED BY VESSEL GROUP					
RIGGING	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	AVERAGE
Standard	43.0	47.3	53.3	46.9	51.1	48.9
7mm Large*	-	-	-	-	55.5	55.5
8mm Small**	45.0	47.4	41.7	46.2	-	45.5
8mm Large	50.2	54.7	51.1	49.9	48.7	50.3
10mm Small	47.3	49.3	50.9	46.3	56.4	51.6
10mm Large	49.7	57.4	54.0	67.1	57.2	57.8
AVE./HR	46.1	50.7	50.7	50.8	53.0	

* This grate was only used with the last group of vessels, when the catch rates were lowest.
** This grate was lost during tests within the fourth group of vessels.

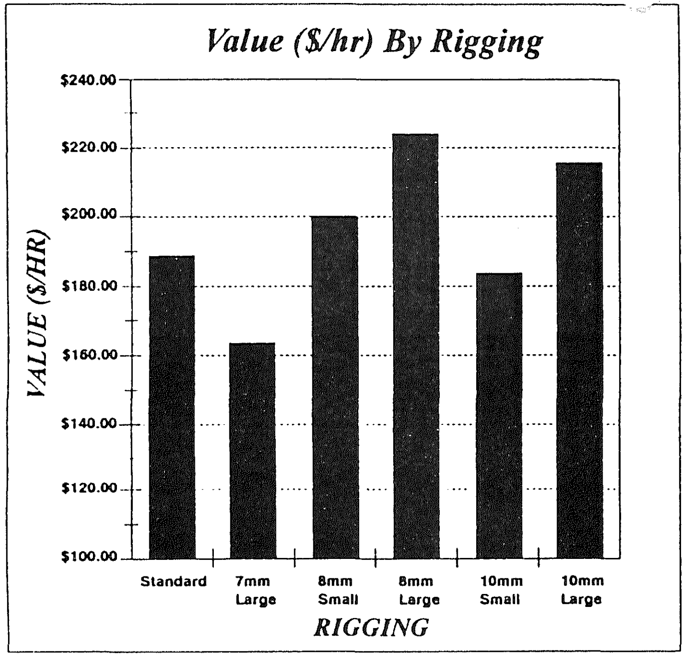


Figure10: A comparison of the catch value/hour obtained when fishing with the various riggings.

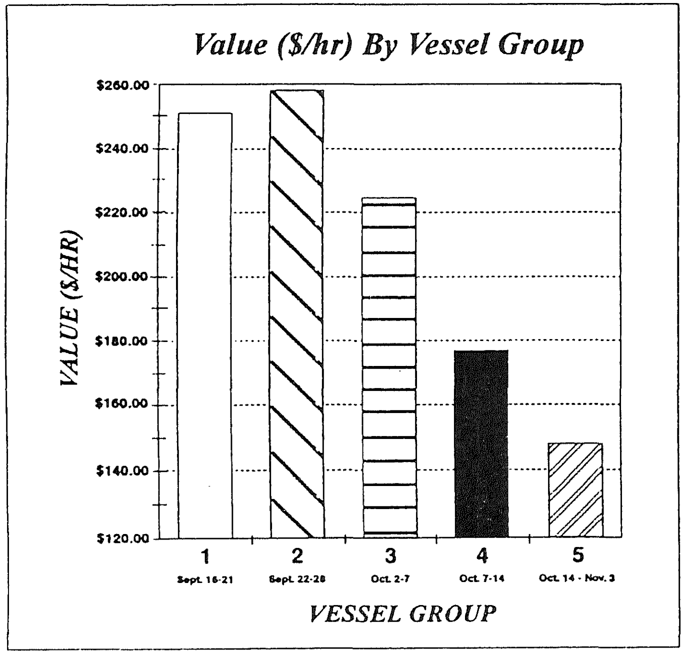
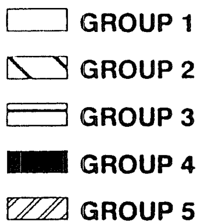


Figure 11: A comparison of the catch value/hour obtained by each group of vessels.



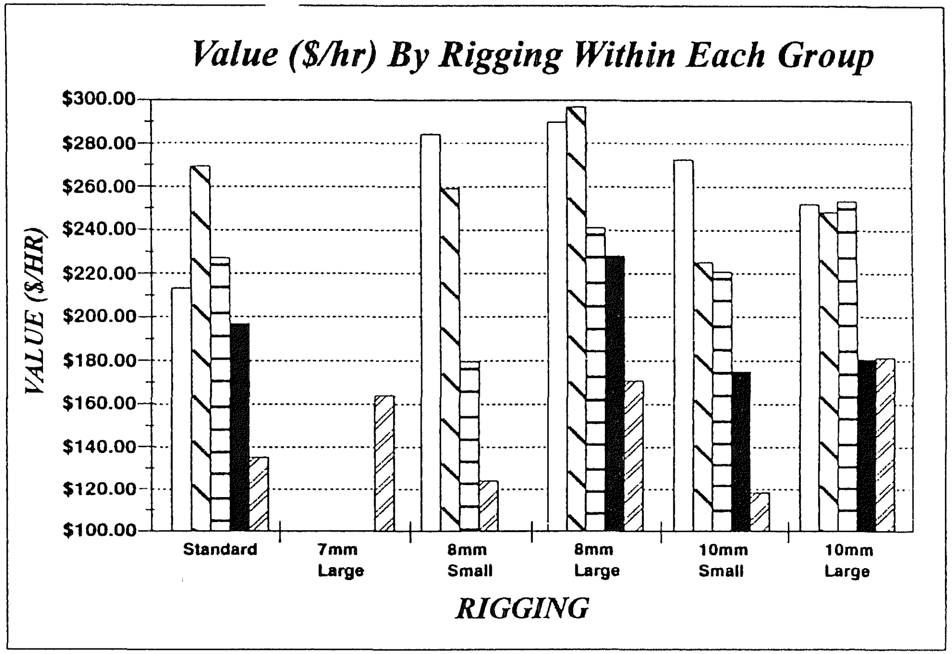


Figure 12: A comparison of the value/hour obtained with the various riggings when used with each group of vessels.

	VALUE ($/HR) FISHING BY VESSEL GROUP					
RIGGING	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	AVERAGE
Standard	213.57	269.26	227.46	198.01	134.83	188.76
7mm Large*	-	-	-	-	163.61	163.61
8mm Small**	284.29	258.41	179.61	123.73	-	199.81
8mm Large	289.68	296.74	241.29	228.31	170.67	224.00
10mm Small	272.30	225.57	221.10	175.12	118.06	183.95
10mm Large	251.93	247.91	252.08	180.93	181.25	215.68
AVE./HR	251.09	257.75	224.54	177.16	147.81	

* This grate was only used with the last group of vessels, when the catch rates were lowest.

** This grate was lost during tests within the fourth group of vessels.

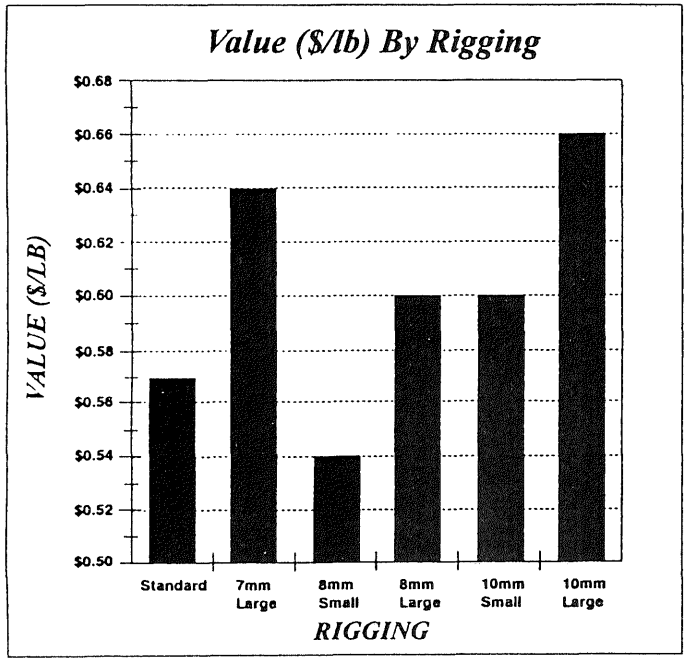


Figure13: A comparison of the catch value ($/lb) obtained for the landed catch when fishing with the various riggings.

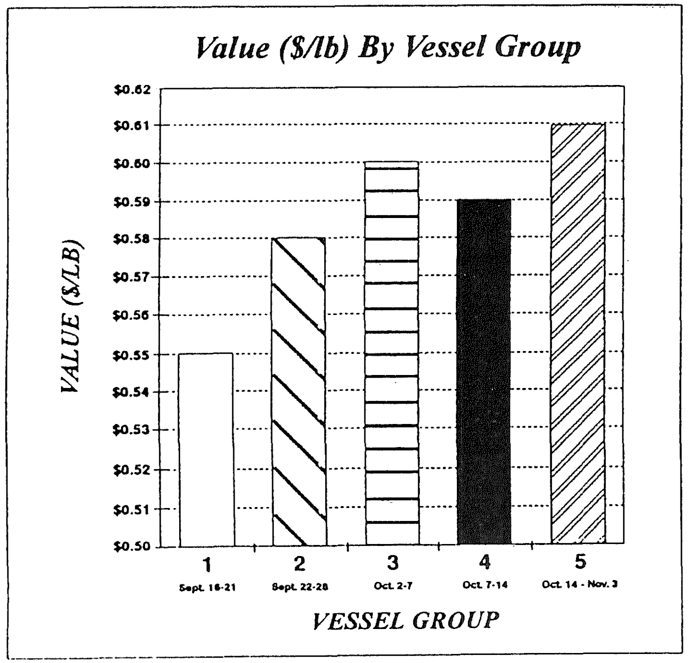
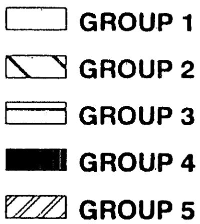


Figure 14: A comparison of the catch value ($/lb) obtained for the landed catch by each group of vessels.



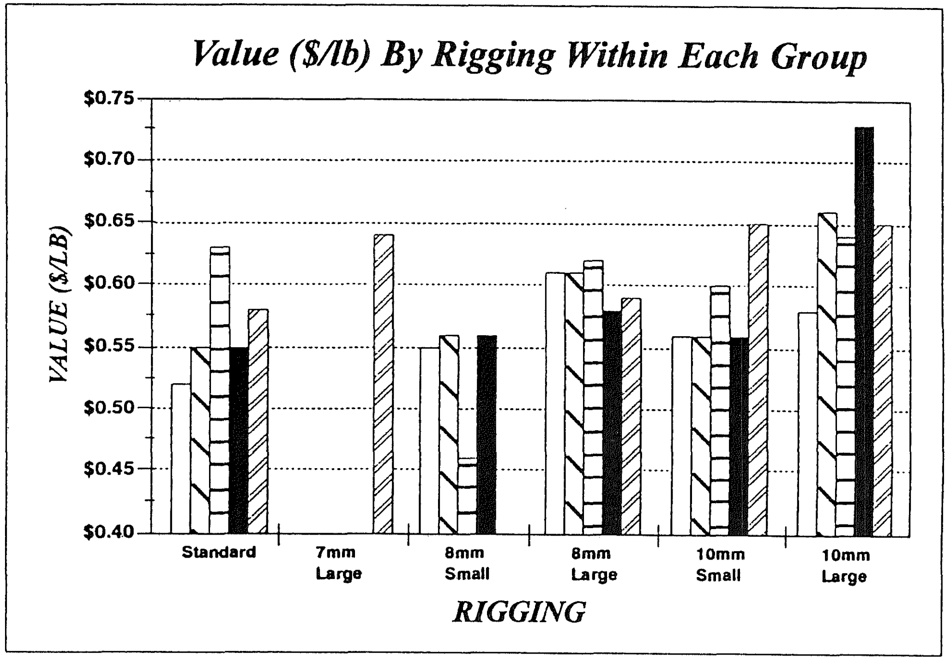


Figure 15: A comparison of the average value/pound obtained for the landed catch when fishing with the various riggings used with each group of vessels.

	VALUE ($/HR) LANDED BY VESSEL GROUP					
RIGGING	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	AVERAGE
Standard	0.52	0.55	0.63	0.55	0.58	0.57
7mm Large*	-	-	-	-	0.64	0.64
8mm Small**	0.55	0.56	0.46	0.56	-	0.54
8mm Large	0.61	0.61	0.62	0.58	0.59	0.60
10mm Small	0.56	0.56	0.60	0.56	0.65	0.60
10mm Large	0.58	0.66	0.64	0.73	0.65	0.66
AVE./HR	0.55	0.58	0.60	0.59	0.61	

* This grate was only used with the last group of vessels, when the catch rates were lov·
** This grate was lost during tests within the fourth group of vessels.

APPENDIX III

Valdemarsen, J.W.
A review of Norwegian research with grid sorting devices in towed fishing gears.

A review of Norwegian research with grid sorting devices in towed fishing gears

John W. Valdemarsen
Institute of Marine Research, Fish Capture Division
P.O. Box 1870, 5024 Bergen, Norway

Brief history

The history of grids as selective devices in Norwegian fisheries dates back to 1989 when the Nordmøre grid was first introduced as a fish bycatch excluder in shrimp trawls. The grid was originally used as a jellyfish excluder by some coastal shrimp fishermen in the Nordmøre district in western Norway, whence its name. First tests of the grid to exclude fish bycatch (mainly cod and haddock) were carried out during the spring of 1989, and within approximately one year its use had been made mandatory in the coastal shrimp fisheries in northern Norway. This successful use of the Nordmøre grid to reduce finfish bycatch stimulated numerous research efforts in Norway to find applications of grid technology in other fisheries as well, mainly for the purposes of size selection. Grid devices to size select fish, shrimp, and Norway lobster have been developed and extensively tested. One such size sorting system (the Sort-X) has been patented and its use will be mandatory in the Barents Sea cod trawl fisheries starting 1 January 1997. A brief description of grid devices tested in different fisheries follows.

Species selective shrimp trawling

The Nordmøre grid developed during 1989-92 and illustrated on Figure 1 is still in use by Norwegian shrimp trawlers. The grid's dimensions will vary depending on the size of vessel and its trawls, but it is typically mounted at a 45-50 degree slope angle and is commonly 1,5 meter long, with widths ranging from 0.7 to 1.5 meters. The inter-bar spacing is a maximum of 19 mm. The grids are normally made from aluminium or stainless steel with the latter as the dominant material among larger vessels. Grids made from rods of glass reinforced plastic installed within a frame of stainless steel pipes have shown promising performance. This material has, however, not been adopted for commercial use to any great extent. At an early stage of grid development a need was identified for an instrument to monitor grid slope and the strength of water flow through the grid. A grid sensor meeting these needs was developed by the Scanmar company in cooperation with the Institute of Marine Research. This instrument is now standard equipment on all larger shrimp trawlers.

Recently, longer grids mounted at a lower slope angle (30 deg.) have been tested. The shrimp loss and fish escapement rates seem to be comparable with the original design. For more detail see Larsen, 1996.

A completely different grid design, the "V-grid" as illustrated in Figure 2, has been developed and prototypes tested in the North Sea and Skagerrak. The intended advantages of this design are better escapement of the smallest fish and provision of a release hole in front of the grid for heavy objects like stones. The design performed well in tests but the shrimp loss rates were somewhat higher than those experienced with the conventional Nordmøre grid.

Size selection of fish by means of grid devices in bottom trawls

The first experiments with grid devices intended to improve the size selection of fish in trawls were conducted in 1990. Various designs were initially tested and the final product was an arrangement which is patented under the name "Sort-X." A full description of this system will be found in Larsen (1996). This device is now used voluntarily by several cod trawlers fishing in the Barents Sea. After 1 January 1997 use of the Sort-X will become mandatory for all Norwegian and other vessels fishing in the Norwegian and Russian zones of the Barents Sea, except for Russian vessels, which will use a grid design developed in Russia which has proved to have selectivity performance similar to the Sort-X.

Size selection of fish with grid devices in Danish seines

Danish seining is a widespread fishing method for cod and haddock along the northern coast of Norway and is also becoming common on offshore grounds in the Barents Sea, particularly in the Bear Island area. Bycatches of undersized fish pose a problem similar to that experienced with bottom trawling. Operational and handling requirements for Danish seining, both during setting and hauling, demand a lighter and more flexible grid system than those that have been developed for trawling. Grids made up in small sections hinged together as shown on Figure 3 have been designed and tested onboard commercial fishing vessels of various sizes. The handling characteristics were acceptable and the selectivity results were at least as good as those obtained with grid systems in trawls.

Size selection of shrimp using various grid devices

Based on the successful use of rigid grids in the aft belly of shrimp trawls to get rid of fish, there has been increasing interest in extend the use of grid technology to sort out undersized shrimp. Bycatches of undersized shrimp present an acknowledged problem in many areas, particularly where quota restrictions favor so called "high-grading" where the valuable large shrimp are kept and sold, while smaller and less valuable shrimp are sorted out of the catch and discarded at sea. The shrimp fishery off Greenland is known to be one where such high-grading is common. In Norwegian regulations the minimum allowable catching size of shrimp is 15 mm carapace length, which is equivalent to 6 cm eye-tail length. When the catch contains more than 10 % undersized shrimp the fishery on that ground is stopped. Since normal diamond meshes have poor size selectivity characteristics, and knowing that shrimp within nets are largely passive with no strongly directed movement, it was believed that a grid could act as a filter allowing small individuals to pass through the grid and towards outlets while larger individuals would be guided by the grid into a codend. Since 1990 several different devices have been tested in Norwegian and Greenland waters as part of a joint Nordic project.

The simplest device tested was similar to a Nordmøre grid but in this case small shrimp passing through the grid were guided out of the trawl with a small mesh guiding funnel. This device was only tested in some preliminary experiments from a small vessel and did not give conclusive results. A major problem clearly identified with this device was that shrimp got stuck on the grid resulting both in reduced filtering area and a "kite" effect where the water pressure forced the grid downward and thus caused the trawl to catch mud.

A second variant of a device to improve shrimp size selection is shown in Figure 4. The grid in this device slopes downward so that any blockage as described above would tend to lift the grid instead of pressing it down. Several design variations have been tested including the use of different materials, gradual increases in bar spacing from front to aft, the attachment of strengthening rods across the grid, and various designs of lifting panels in front of the grid, including a front grid. The various designs were tested in Greenland waters at catch rates ranging from 100 to 1000 kg/h. These grid systems performed in a technically acceptable manner but shrimp size selection was not much improved compared to ordinary mesh selection. An apparent disadvantage with this approach is that large objects will pass by the grid system only with difficulty.

A third system designed for shrimp size selection consisted of a guiding funnel that centered all organisms before they hit a hinged, V-shaped grid with the apex pointing forward (See Fig. 5b for a similar arrangement). Since the shrimp encounter both an upper and lower grid any blocking will tend to be balanced. This system required a passage for larger individuals above and below the grid into the codend. Testing of this device was conducted in the Skagerrak region.

Combined grid devices for shrimp size selection and fish bycatch reduction

In most shrimp fisheries in Nordic waters, grids for fish bycatch exclusion are or will soon be mandatory. Any additional devices or modifications for improving shrimp size selectivity must therefore be compatible with finfish excluders. Three different concepts aimed at this combined capability have been developed and tested in Norway and Greenland under the framework of the Nordic project. One of the devices was simply a combination of the Nordmøre grid shown in Figure 1 with a second sloping grid. Only some preliminary testing was done with this device including video observations from a towed underwater vehicle.

A second dual-purpose device was extensively tested off West Greenland in 1992 and is illustrated in Figure 5a and 5b. This arrangement is a combination of the V-grid designed for fish exclusion (Figure 2) and a shrimp size selector. The operating principle of this device was that larger organisms like fish and heavy objects would be removed first and that only shrimp and very small fish would hit the grid where shrimp size selection would take place. It was tested in two orientations, as shown. The selectivity results obtained with this device were among the best yet for shrimp size selection but there was some loss of commercial sized shrimp. The major disadvantages of this device were that it is rather complicated in construction and its performance is sensitive to the conditions of use.

A third dual-purpose device is illustrated in Figure 6. It is quite similar to an ordinary Nordmøre grid but with the lower and front half of the grid constructed with smaller bar spacings to carry out shrimp size selection, guiding the larger shrimp towards the second, upper grid. Shrimp can easily pass through this grid and into the codend, while finfish are guided towards the escape outlet. The grid proved to be easy to handle but the shrimp size-selectivity performance was still not adequate. The loss of commercial shrimp was relatively low and the fish escapement was comparable to the normal Nordmøre grid.

Size selectivity for Norway lobster

In the Norwegian sector of the North Sea and in the Skagerrak the minimum legal size for Nephrops is 40 mm carapace length. Codends made of ordinary diamond meshes of 70 mm (the legal minimum) retain too many undersized nephrops. In addition to experiments with square mesh codends, various grid-based systems have been tested in this fishery.

The first variant is illustrated on Figure 7. It consists of a double grid hinged together and sloping downward at 30 deg from the top panel. The trawl's bottom panel in front of the grid was lifted by means of 2 or 3 floats attached under the panel, thus directing fish and nephrops against the grid. Selectivity performance was better than that experienced with diamond and square mesh codends tested at the same time.

A second arrangement tested for nephrops size selection is illustrated in Figure 8. All organisms are guided by a leading panel made of small square mesh towards the bottom panels where a grid one meter long rises upwards at a 30 degree angle. Small nephrops passing through the grid are then guided out of the trawl. The results from these experiments were encouraging as good nephrops size selectivity was achieved and there were only minor handling problems.

Future development

The willingness of fishermen to use rigid structures within flexible trawls and seines opens the door to further improvements of the selectivity performance of fishing gears. The few successful applications of grids that have been developed so far represent only the beginning. Likely trends for further development include more functional designs and the use of lighter, stronger, and/or more flexible materials. The rigid structure itself can be a platform for instrumentation, for monitoring the selection process, and for other hardware that could stimulate the escape of unwanted organisms.

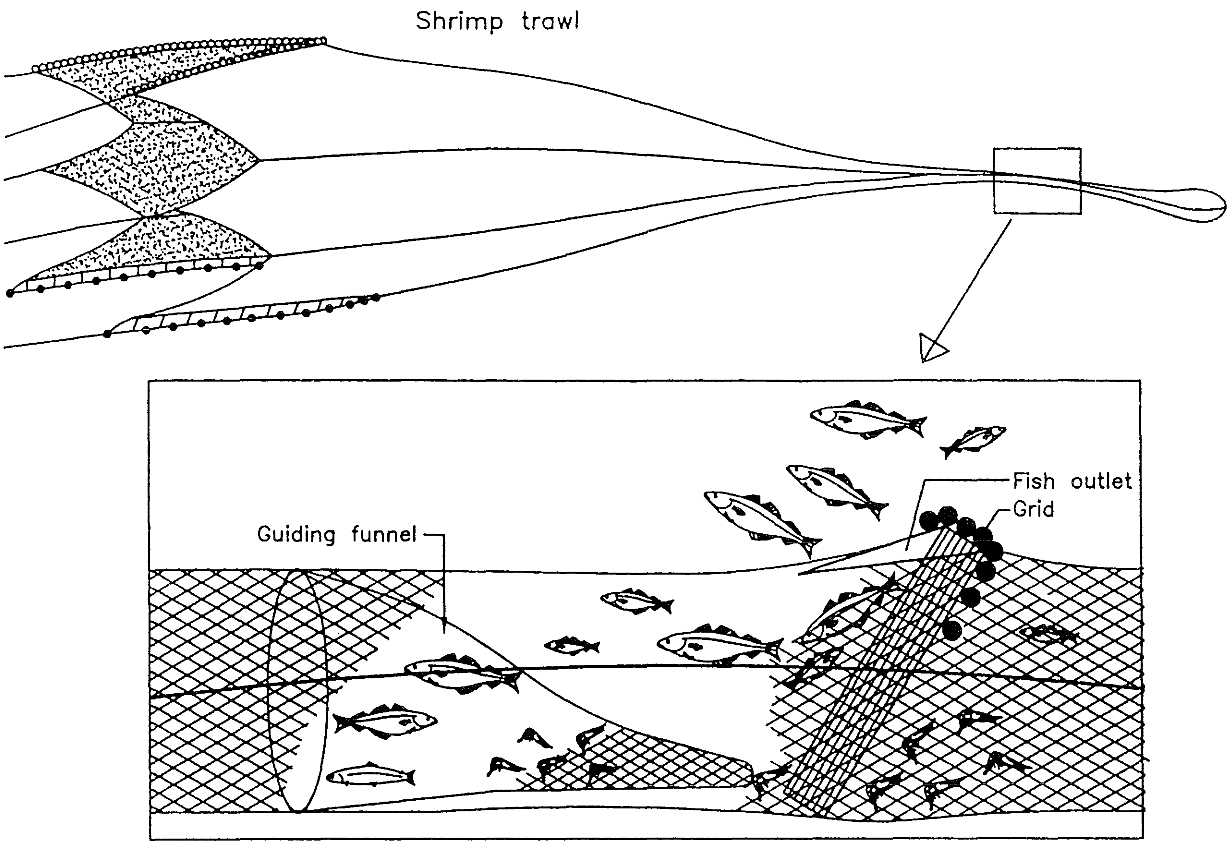


Figure 1. Nordmøre grid shrimp–fish separating system

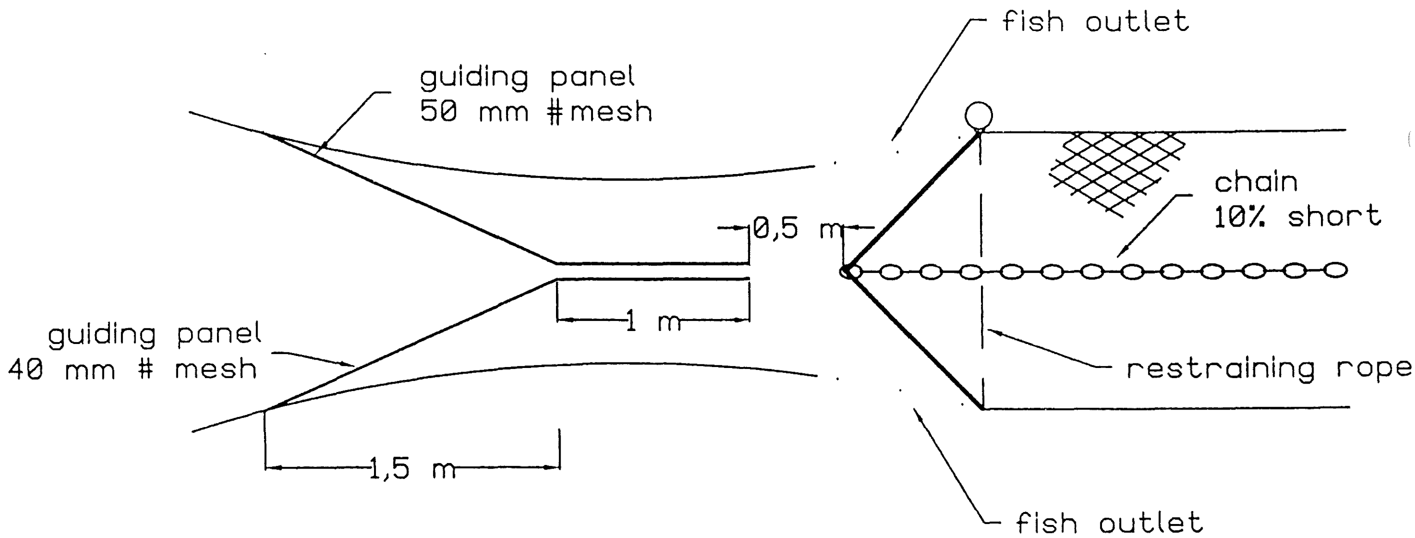


Figure 2. "V–grid" shrimp–fish separating system

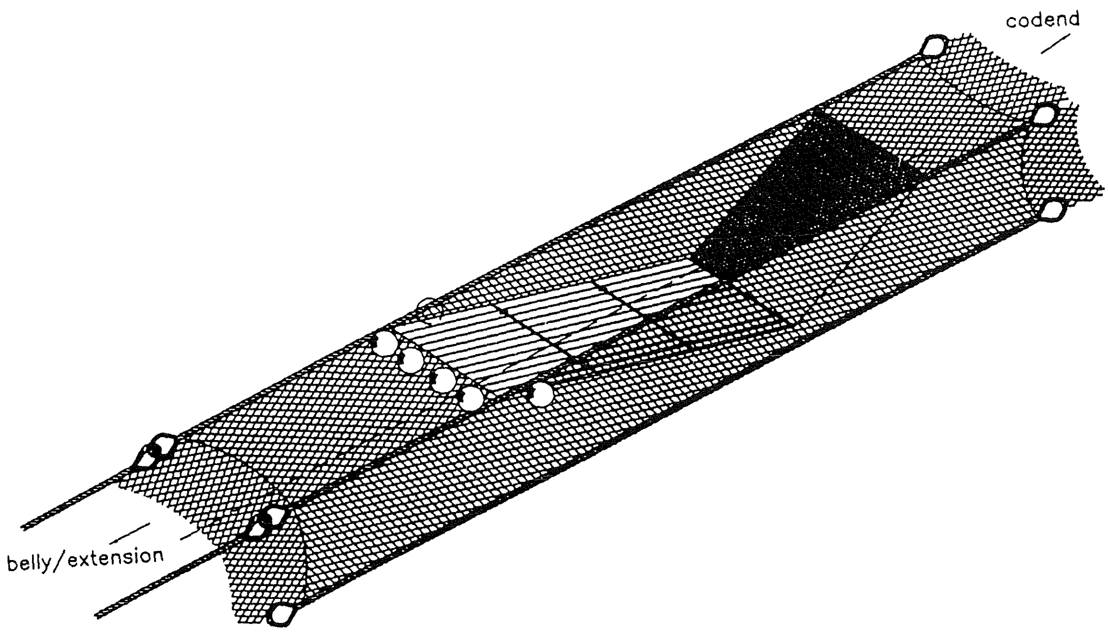


Figure 3. Typical grid installation for Danish seines

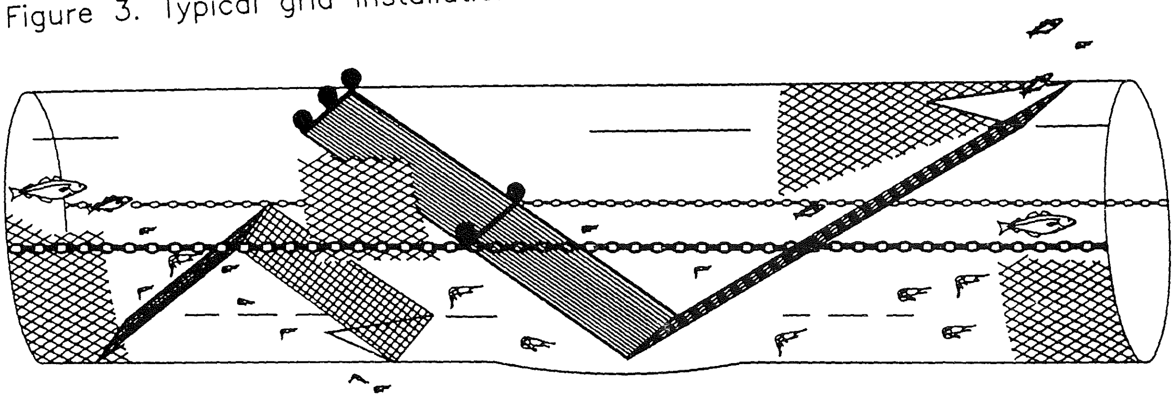


Figure 4. Grid system for releasing small shrimp & small fish

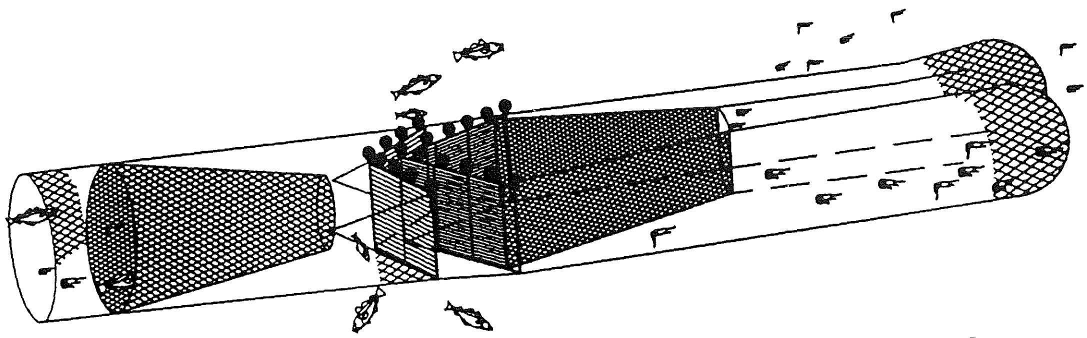


Figure 5a. "plow" mode

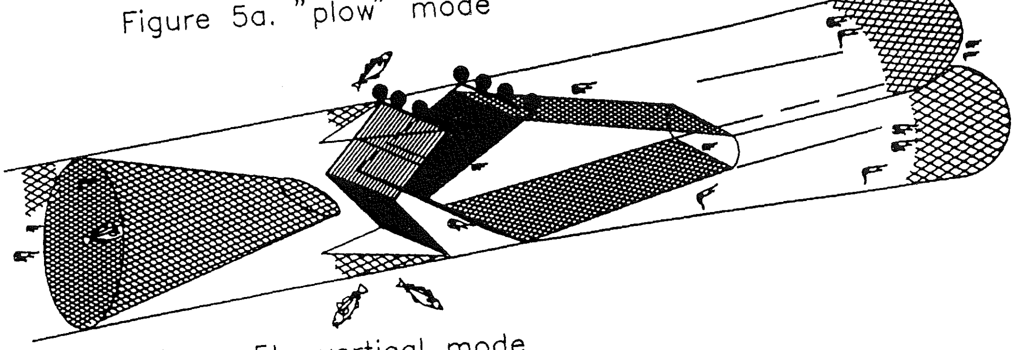


Figure 5b. vertical mode

Figure 5. V-grid system for releasing small shrimp and fish of all sizes

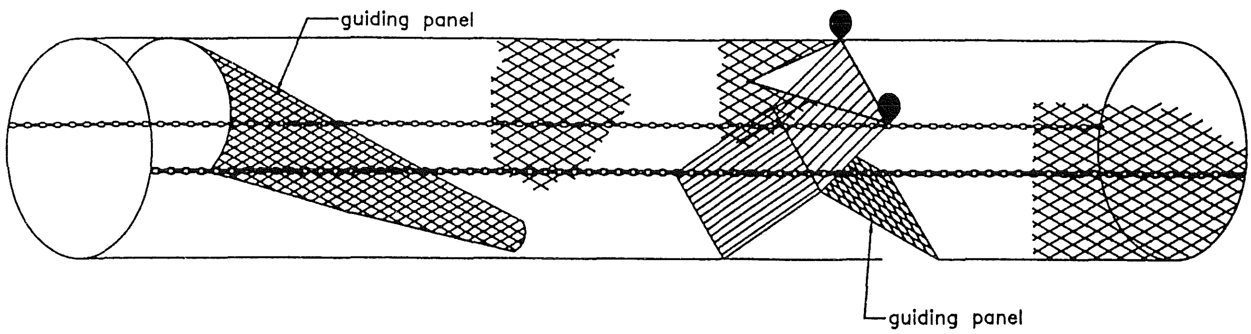


Figure 6. Grid system for releasing small shrimp and all fish

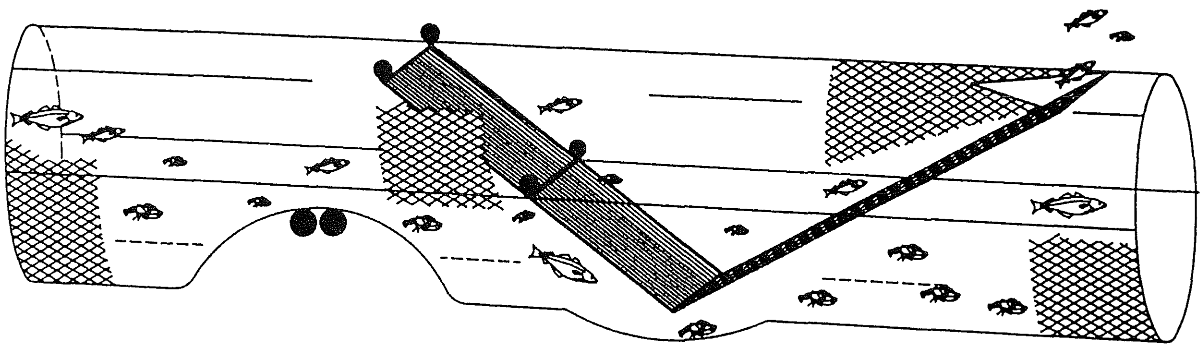


Figure 7. Grid system for releasing small nephrops and small fish

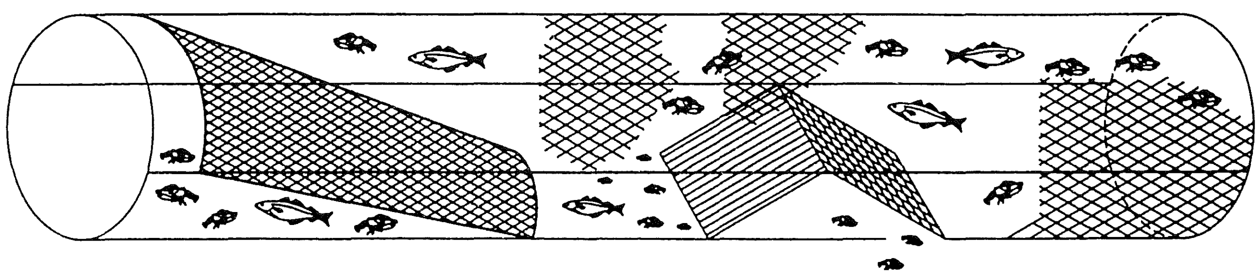


Figure 8. Grid system for releasing small nephrops

APPENDIX IV

Larsen, R.
Construction and description of Sort-X and top-cover used during selectivity trials & examples of results obtained during 1994-1996 on different species of bottom fish.

NOT TO BE CITED WITHOUT PRIOR REFERENCE TO THE AUTHOR

ICES FTFB W.G. Meeting, Woods Hole, USA, 15-18 April 1996

Construction and descriptions of Sort-X and top-cover used during selectivity trials & examples of results obtained during 1994-1996 on different species of bottom fish

Roger B. Larsen

April 1996

The Norwegian College of Fishery Science - University of Tromsö, N-9037 Tromsö, Norway

1. Sorting grids - Sort-X

The pilot test with a sorting grid for fish *size* selection was made autumn 1989 (Larsen 1989). During 1990 several experiments were carried out to find a suitable technical solution and to verify the results through selectivity trials and underwater observations (Larsen 1990 a, b, Larsen & Isaksen 1993). Since May 1990, no major changes have been made on the sorting grids (i.e. Sort-X).

Throughout the testperiods during 1990 - 1995 (see enclosure I), most of the work has been made in cooperation with the Directorate of Fisheries (Bergen) and the Institute of Marine Research (Gear Division, Bergen). In 1992 (Larsen et al. 1992) and in 1995 (Isaksen et al. 1995) joint selectivity experiments were made together with russian collegueas from the Polar Institute of Marine Research and Ocenography (PINRO) in Murmansk.

Most of the work with Sort-X has been made on Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*), but during the years 1992-1995 the size selectivity with Sort-X was also tested for species like saithe (*Pollachius virens*), redfish (*Sebastes marinus* and *S. mentella*) and the flatfish species Greenland halibut (*Reinhardtius hippoglossoides*). During these trials the bar distance (opening) in the Sort-X was changed between 40, 45, 50 and 55 mm. Additionally, the codend mesh size was altered between the standard 135 mm and 100 mm (Larsen 1993, Larsen & Schultz 1993, Larsen & Gamst 1995a, 1995b).

A small version of the Sort-X was tested on board smaller vessels (20 m l.o.a.) during cruises in 1991 and 1992 (Marteinsson & Schultz 1991). In both cases the vessel had a netdrum on the stern, and the catches were taken on board along the side of the vessel.

Since 1993 several norwegian trawlers have used the Sort-X system on a voluntary basis in the fishery for cod, and by the end of February this year more than a 100 trawlers are equipped with Sort-X systems (see enclosure II). Most of these vessels are using larger bar openings (80-120 mm) than the 55 mm bar opning which matches the minimum landing sizes of fish. Results on cod with different bar openings in the Sort-X were obtained during trials in 1995 and 1996 (Larsen 1996).

2. Top-cover

In order to investigate the sorting ability of the Sort-X, a special cover had to be designed to retain all fish escaping through the grid (Larsen 1990a, Larsen & Isaksen 1993). Originally the top-cover was made of 1.8 mm polyetylene (PE, courlene) with a mesh size of 48 mm (mesh length 52 mm) and with a strengthening bag around the last section. The total length of the cover equals 23 m. During experiments on board larger factory trawler and under conditions with large catches, especially during selectivity trials on redfish and Greenland halibut, it became necessary to strengthen the whole cover with double 4 mm PE of 145 mm mesh size. (Larsen & Gamst 1995a, Isaksen et al. 1995, Larsen & Gamst 1995b).

The top-cover has been used successfully in both trials with fish trawl and shrimp trawls. Underwater observations shows the cover opens well above the grid section, the heigth has been estimated to close to 4 m during towing speeds around 4 knots (Larsen & Isaksen 1993). During several experiments it has been shown that the top-cover has no effect on the selectivity results, even with large numbers of fish inside the top-cover (Larsen & Gamst 1995a).

When the top-cover is used during selectivity trials on fish, the effect of the grids are seen directly if the codend of the trawl simultaneously is "blinded" with an innernet (liner) equal in mesh size to the top-cover. "Blinders" are used to prevent codend mesh selection (additional selection during grid trials), which would bias the results of grid selection. This technique has been used in almost all the norwegian trials with Sort-X during 1990-1995 made in areas where the legal mesh size of codends are minimum 135 mm.

References

Isaksen, B., Lisovsky, S., Larsen, R.B. and Sakhnoe,V. 1995. Results from joint Russian-Norwegian selectivity experiments on cod (*Gadus morhua* L.) in the Barents Sea with 55 mm sorting grid systems 15-26 September 1995. Institute of Marine Research, Bergen. 38 pp.

Larsen, R.B. 1989. Pilotforsøk med ny teknologi i torsketrål for å unngå fangst av småfisk. Norges fiskerihøgskole, UiTø. 10 sider.

Larsen, R.B. 1990a. A new approach of size selectivity in commercial codfish trawls using the "trollex" system. ICES W.G. Meeting, Fish Capture Committee, Rostock, April 23-27 1990.

Larsen, R.B. 1996: Construction and descriptions of Sort-X and top-cover used during selectivity trials & examples of results obtained during 1994-1996 on different species of bottom fish. *ICES FTFB W.G. Meeting, Woods Hole, USA, April 1996.*

Larsen, R.B. 1990b. Utprøving av ny sorteringsteknologi for kommersiell torsketrål. Seleskjonsforsøk, mai 1990 med M/S "Remifisk". Norges fiskerihøgskole, UiTø. 35 sider.

Larsen, R.B. 1991. Sluttrapport for trollex prosjektet. Forsøk med sorteringsrister i torsketrål. Norges fiskerihøgskole, UiTø. 31 sider.

Larsen, R.B. 1992. A short history on the development of the Sort-X system for size selectivity of fish. Newfoundland and Nova Scotia Moblie Gear Selectivity Workshop, Canada April 1992. Technical report, Fisheries and Oceans. Ottawa. pp 41-69.

Larsen, R.B. 1993. Utprøving av 50 mm Sort-X på uer, blåkveite og sei. Forsøk ombord i F/F "Jan Mayen" i tiden 18.-28. august 1993 på fiskefelt fra Troms til Bjørnøya. Norges fiskerihøgskole, UiTø. 22 sider.

Larsen, R.B. 1996. Resultater med 55, 80 og 100 mm Sort-X på torsk og hyse i 1995 og 1996. Forsøk om bord i F/F "Jan Mayen" på fiskefeltene utenfor Troms og Finnmark. Norges fiskerihøgskole, UiTø. in prep.

Larsen, R.B. and Isaksen, B. 1993: Size selectivity of rigid sorting grids in bottom trawls for Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). ICES Mar. Sci. Symp., 196: 178-182.

Larsen, R.B. og Gamst, K. 1995a. Direktefiske etter sei (*Pollachius virens*) med 50 mm sorteringsrist (Sort-X) kombinert med 100 mm maskevidde i trålposen i torsketrål. NFH-UiTø/Fiskeridirektoratet. 35 sider.

Larsen, R.B. og Gamst, K. 1995b. Fangstforsøk på blåkveite (Reinhardtius hippoglossoides) og uer (Sebatses spp.) med sorteringsrist i torsketrål. Forsøk ombord i F/Tr. "Hopen" i tiden 7. til 22. november 1994 langs Fugløybanken og Tromsøflaket. 40 sider.

Larsen, R.B., Lisovsky, S, Isaksen, B., Sakhno, V.A. and Marteinsson, J.E. 1992: Experiments with Sorting Grid (Sort-X) made by Russian and Norwegian Trawlers in July 1992. Report to the Mixed Norwegian-Russian Fishery Commission, 21th Session. 43 pp.

Larsen, R.B. og Schultz, B. 1993. Sorteringsrist i torsketrål (50 mm Sort-X) kombinert med 100 mm maskevidde i trålposen. Forsøk ombord i F/T "Eldborgtrål" 14.-21. oktober 1993. NFH-UiTø/Fiskeridirektoratet. 7 sider (+ vedlegg).

Marteinsson, J.E. & Schultz, B. 1991: Utprøving av sorteringsrist (Sort-X) i torsketrål på småtråler. Fiskeridirektoratet, Fondet for fiskeleting og forsøk, Rapporter nr. 3 og 4 1992. pp 130-148.

Enclosure I: Test periods with Sort-X during March 1990 to September 1995. * Russian vessels.

Periods days	Vessels	Sort-X type bar distance	Species tested
March1990 16 days	"Anny Kræmer" 51.8 m/2400 hk	50 mm, 52 mm , 55 mm og 60 mm	cod, haddock
May 1990 10 days	"Remifisk" 32.5 m/660 hk (nettrull)	55 mm	cod, haddock
Aug./Sept. 1990 14 days	"Anny Kræmer" 51.8 m/2400 hk	55 mm	cod, haddock, saithe
November 1990 8 days	"Prestfjord" 56.9 m/3000 hk	55 mm	cod, haddock
May/June 1991 14 days	"Genichesk"* 59.0 m/2200 hk	55 mm	cod, haddock
Aug./Sept. 1991 12 days	"Skjervøyfisk" 46.7 m/1250 hk	55 og 50 mm	cod, haddock, saite, redfish
Oct./Nov. 1991 20 days	"Novoazovsk" * 59.0 m/2200 hk	55 mm	cod, haddock
November 1991 10 days	"Prestfjord" 56.9 m/3000 hk	50 og 40 mm	cod, haddock, Greenland halibut, redfish
November 1991 12 days	"Gullstad" 19.9 m/500 hk (nettrull)	55 mm (small Sort-X version)	cod, haddock, saite, redfish
March 1992 11 days	"Prestfjord" 56.9 m/3000 hk	40, 45 og 50 mm	redfish, saithe, Greenland halibut, haddock
March 1992 20 days	"Formalhaut" * 54.8 m/1000 hk	55 mm	cod, redfish
May 1992 10 days	"Fröybanken" 19.6 m/500 hk (nettrull)	55 mm (small Sort-X version)	cod, haddock, saithe
July 1992 17 days	"Anny Kræmer" 51.8 m/2400 hk	55 mm	cod, haddock
July 1992 10 days	"Poljarnoje Sijanije" * 83.1 m/2400 hk	55 mm	cod
October 1992 9 days	"Kirkøy" 46.2 m/1630 hk	50 og 55 mm	cod, haddock, saite, redfish
March 1993 10 days	F/F "Jan Mayen" 63.8 m/4080 hk	55 mm	cod, haddock
August 1993 10 days	F/F "Jan Mayen" 63.8 m/4080 hk	50 mm	saithe, Greenland halibut, haddock
October 1993 7 days	"Eldborgtrål" 57.9 m/4080 hk	50 mm	saithe
March 1994 10 days	F/F "Jan Mayen" 63.8 m/4080 hk	55 mm	cod, haddock
July/Aug. 1994 14 days	"Rosund" 48.7 m/2250 hk	50 mm	saithe, Greenland halibut
November 1994 15 days	"Hopen" 60.5 m/4000 hk	50 og 55 mm	Greenland halibut, redfish
March 1995 10 days	F/F "Jan Mayen" 63.8 m/4080 hk	50, 55 og 80 mm	cod, haddock
March/April 1995 14 days	"Ramoen" 67.4 m/4590 hk	145, 50 og 55 mm	redfish, haddock, Greenland halibut, saithe
September 1995 17 days	"Anny Kræmer" 51.8 m/2400 hk	55 mm	cod, haddock

Enclosure II: The number of complete Sort-X systems delivered to trawlers by 12.02.96.

	Big trawls	Small trawls	Total
The number of Norwegian trawlers with the Sort-X system on board	80	20	100
The number of Norwegian trawlers with 2 complete Sort-X systems	15	-	15
The number of Norwegian trawlers with 3 complete Sort-X systems	3	-	3
The number of foreign trawlers with the Sort-X system on board	8	-	8
The number of foreign trawlers with 2 complete Sort-X systems	1	-	1
A total number of delivered complete Sort-X systems	107	20	127

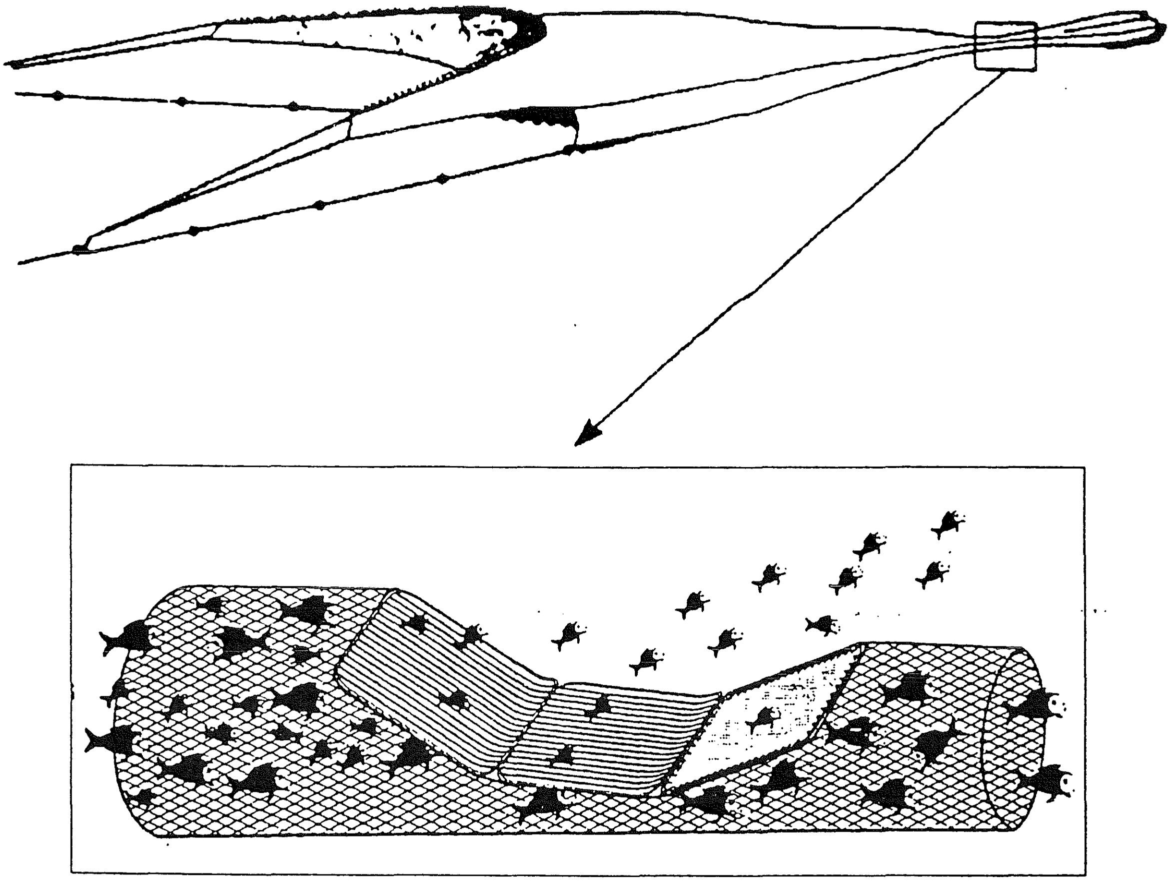
Table 2. The number of extra 1st (front) and 2nd (middle) sorting grids (with the bar distance more than 55 mm) and cassettes delivered by 12.02.96 to trawlers which fish in Norwegian economic zone.

Bar distance	Extra 1st sorting grids (front)		Extra 2nd sorting grids (middle)		Cassettes for the 1st sorting grids (front)		Cassettes for the 2nd sorting grids (middle)	
	Big trawls	Small trawls	Big trawls	Small trawls	Big trawls	Small trawls	Big trawls	Small trawls
70 mm	4	-	1	-				
80 mm	60	8	-	-				
90 mm	2	-	1	-				
100 mm	2	1	-	-				
120 mm	3	-	-	-				
Sum	71	9	2	-	70	12	3	-
Total sum	80		2		82		3	

Sort-X

SELECTIVE FISHING TECHNOLOGY

Working Principle



The Sort-X system is patented and can not be produced without permission from Selfi A/S, Postboks 746, N-9001 Tromsø, Norway

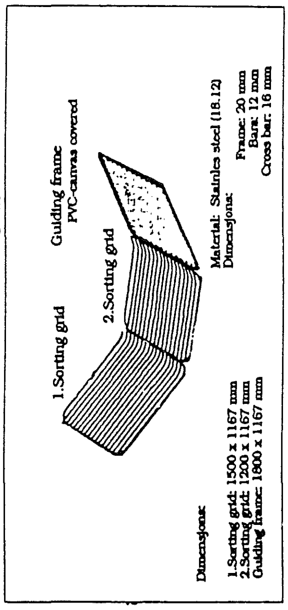
Avd./Serie Dept./Series	Type Type Sort-X An indication of where the sorting grids are placed in the existing trawl	SELFI A/S Sort-X SELECTIVE FISHING TECHNOLOGY
Ref. Ref. STX008E		
Nr. No.		
Erstatter Replaces		

Erst. av Repl. by	Skala Scale	Konstr. Constr.	Godkj. Approv	Dato Date	Sign. Sign.
			M.D.	29.03.93	J.E.M.

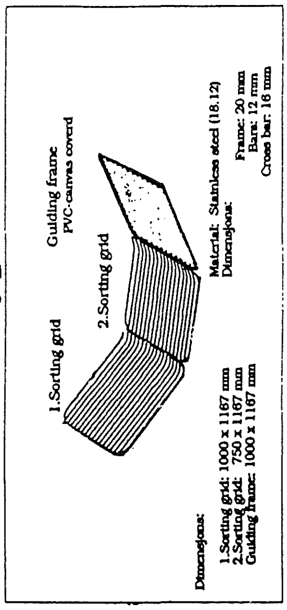
Sort-X
SELECTIVE FISHING TECHNOLOGY

Construction of the sorting grids

Standard type



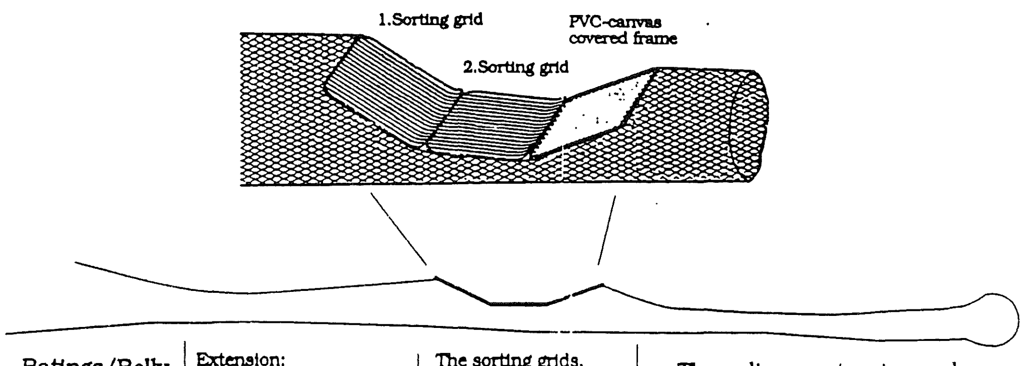
Small type



Avd./Serie Dept./Series	Type Type	
Ref. STX011 Ref.	Sort-X	SELFI A/S
Nr. No.	Construction of the sorting grids	Sort-X SELECTIVE FISHING TECHNOLOGY
Erstatter Replaces		
Erst. av Repl. by	Skala Scale / Konstr. Constr. / Godkj. Approv M.D.	Dato Date 20.05.93 / Sign. Sign. J.E.M.

Sort-X
SELECTIVE FISHING TECHNOLOGY

Principle sketch for the attachment to the trawl



Batings/Belly	Extension: Standard type: 10 meter Small type: 8 meter	The sorting grids. Standard type. 4,5 m Small type: 2,75 m	The ordinary extension and codend of the existing trawl

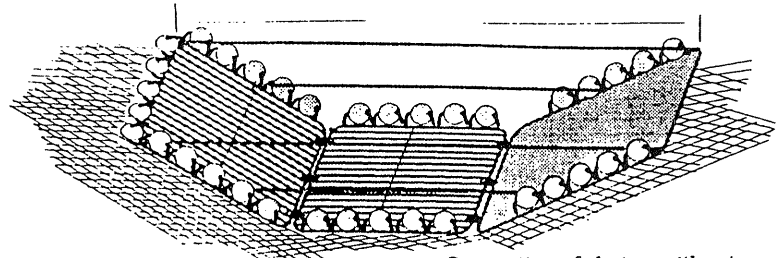
The Sort-X system

Avd./Serie Dept./Series	Type Type	
Ref. STX010E Ref.	Sort-X	SELFI A/S
Nr. No.	Principle sketch for the attachment to the trawl	Sort-X SELECTIVE FISHING TECHNOLOGY
Erstatter Replaces		
Erst. av Repl. by	Skala Scale / Konstr. Constr. / Godkj. Approv	Dato Date 20.05.93 / Sign. Sign. J.E.M.

Sort-X Standard type

SELECTIVE FISHING TECHNOLOGY

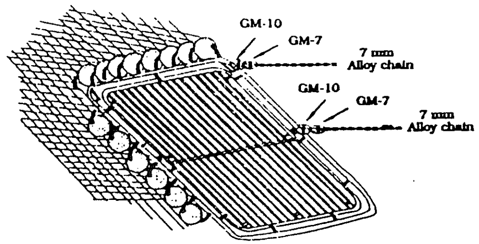
The length of the chain given as the total length between the frames of the end-modules



Connecting of chain - with cassette

No. of Floats
- 1.Sorting gridt: 20
- 2.sorting grid: 10
- Guiding frame: 10

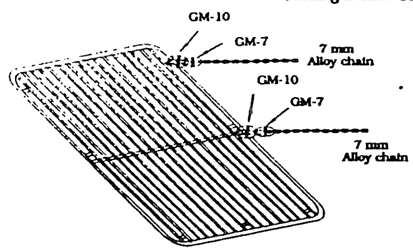
Upper chain: 4.36 m
Lower chain: 2.78 m



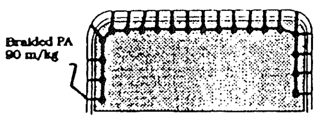
Connecting of chain - without cassette

Upper chain: 4.24 m
Lower chain: 2.72 m

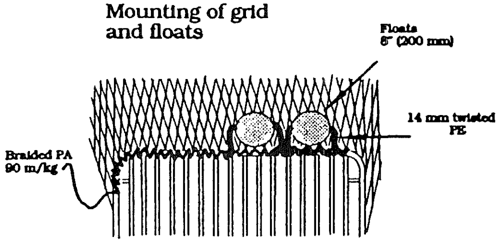
No. of Floats:
- 1. Sorting grid: 15
- 2. Sorting grid: 10
- Guiding frame: 10



Mounting of PVC-Canvas



Mounting of grid and floats

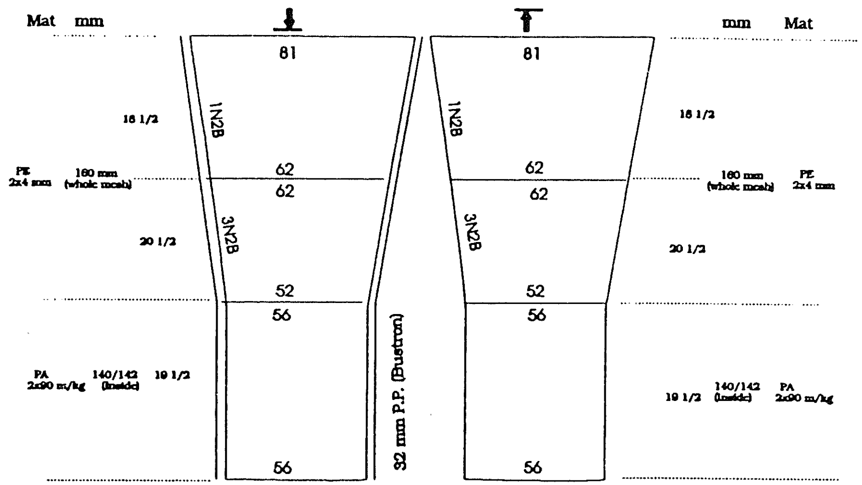


Avd./Serie Dept./Series	Type Type: Sort-X - Standard type	SELFI A/S Sort-X SELECTIVE FISHING TECHNOLOGY
Ref. Ref.: STX001E	Mounting of chain and floats	
Nr. No.		
Erstatter Replaces		
Erst. av Repl. by	Skala Scale / Konstr. Constr. / Godkj. Approv: M.D.	Dato Date: 15.05.93 / Sign. Sign: J.E.M.

Sort-X Standard type

SELECTIVE FISHING TECHNOLOGY

Extension in front of the sorting grids



Avd./Serie Dept./Series	Type Type: Sort-X - Standard type	SELFI A/S Sort-X SELECTIVE FISHING TECHNOLOGY
Ref. Ref.: STX002E	Extension in front of the sorting grids	
Nr. No.		
Erstatter Replaces		
Erst. av Repl. by	Skala Scale / Konstr. Constr. / Godkj. Approv: M.D.	Dato Date: 02.11.93 / Sign. Sign: J.E.M.

STANDARD TYPE

2. TECHNICAL SPECIFICATIONS

NETTING SECTIONS

	Material	Twine	Mesh size - inside
Grid-section	P.A. (Nylon)	Braided. 90 m/kg (6 mm) impregnated	140/142 mm
Extension	P.A. (Nylon)	Braided. 90 m/kg (6 mm) impregnated	140/142 mm
Extension	P.E. (Courlene)	190 m/kg Braided (4 mm) - Double	160 mm (whole)

Lastridge rope:	P.P. (Bustron) 32 mm
Attachment of the lastridge rope:	P.A. Braided. 280 m/kg - impregnated
Lacing twine:	P.A. Braided. 280 m/kg - impregnated
Twine for mounting of grids:	P.A. Braided. 90 m/kg (6 mm)-impregnated
Twine for mounting of PVC-canvas:	P.A. Braided. 90 m/kg (6 mm)-impregnated
Rope for mounting floats:	14 mm P.E. Twisted

GRIDS

Material : High quality steel (18.12) - Quality: SIS 2343

	1. Sorting grid	2.Sorting grid	Guiding frame
Dim. frame	20 mm	20 mm	20 mm
Dim. bars	12 mm	12 mm	
Dim. longitud. bars	16 mm	16 mm	16 mm
Dim. cross bars			20 mm

PVC-Canvas — PVC-Coated fabrics 890 g/m² (Polymar 8556) with eyelets (15/37) melded along the borders.
- Distance between eyelets: - On the sides: aprox. 6 cm
- Top/bottom:approx. 10 cm

CASSETTE FOR REPLACING THE 1. SORTING GRID

Dimension frame: 20 mm
Number of holding grips:
-On the sides: 3 -At the top: 1 At the bottom: 2

CHAIN, CHAIN CONNECTORS AND FLOATS

Chain	: 7 mm shortlink (7x23 mm) Alloy chain (Grade 80)
Connecting of chain	: Alloy connecting link GM-7 Alloy connecting link GM-10
Connecting of grids	: Alloy connecting link GM-10
Floats:	: Plastic - 8" (200 mm)

SMALL TYPE i.e. Vessels > 30.0 m.

2. TECHNICAL SPECIFICATIONS

NETTING SECTIONS

	Materiale	Twine	Mesh size - inside
Grid-section	P.A. (Nylon)	16-lay Braided. 150 m/kg impregnated	140/142 mm
Extension	P.A. (Nylon)	16-lay Braided. 150 m/kg impregnated	140/142 mm

Lastridge rope:	P.P. (Bustron) 24 mm
Attachment of the lastridge rope:	16-lay Braided. 280 m/kg - impregnated
Lacing twine:	16-lay Braided. 280 m/kg - impregnated
Twine for mounting of grids:	16-lay Braided. 90 m/kg (6 mm) - impregnated
Twine for mounting of PVC-canvas:	16-lay Braided. 90 m/kg (6 mm) - impregnated
Rope for mounting floats:	14 mm P.E. twisted

GRIDS

Material : High quality steel (18.12) - Quality: SIS 2343

	1. Sorting grid	2.Sorting grid	Guiding frame
Dim. frame	20 mm	20 mm	20 mm
Dim. bars	12 mm	12 mm	
Dim. longitud. bars	16 mm	16 mm	16 mm
Dim. cross bars			20 mm

PVC-Canvas — PVC-Coated fabrics 890 g/m² (Polymar 8556) with eyelets (15/37) melded along the borders.
- Distance between eyelets: - On the sides: approx.. 6 cm
- Top/bottom: approx. 10 cm

CASSETTE FOR REPLACING OF THE 1. SORTING GRID

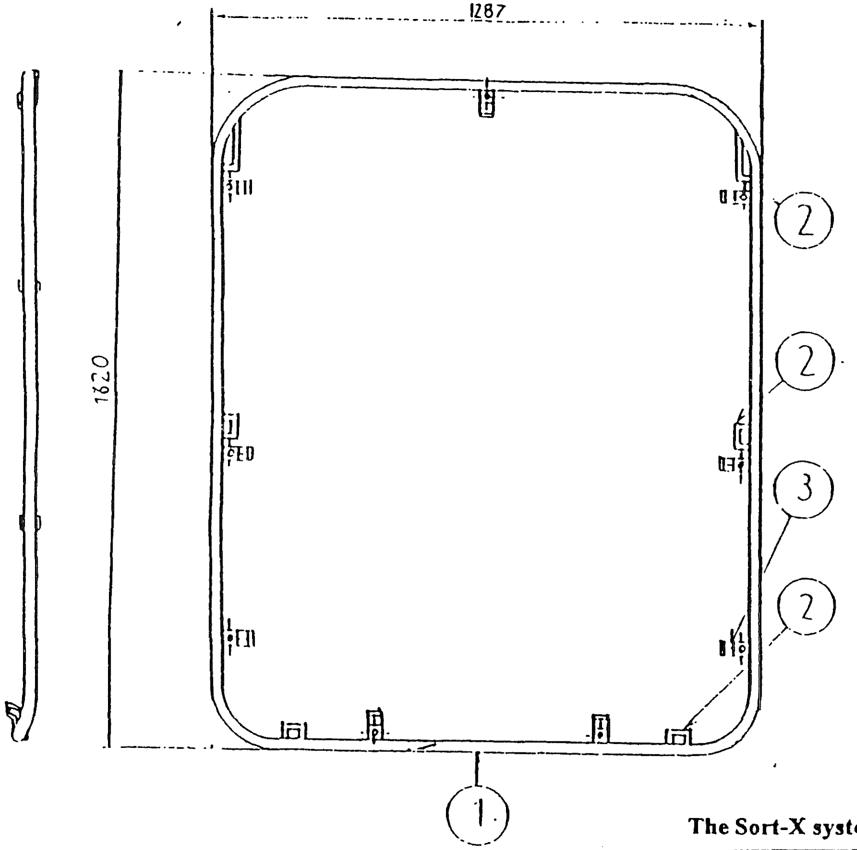
Dimension frame: 20 mm
Number of holding grips:
-On the sides: -At the top: At the bottom:

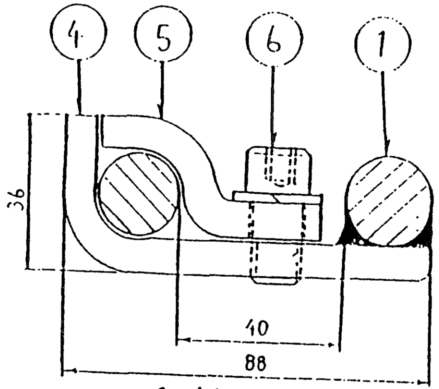
CHAIN, CHAIN CONNECTORS AND FLOATS

Chain	: 7 mm shortlink (7x23 mm) Alloy chain (Grade 80)
Connecting of chain	: Alloy connecting link GM-7 Alloy connecting link GM-10
Connecting of grids	: Alloy connecting link GM-10
Floats:	: Plastic, 8" (200 mm)

Sort-X
SELECTIVE FISHING TECHNOLOGY

Cassette for replacing 1. Sorting grid





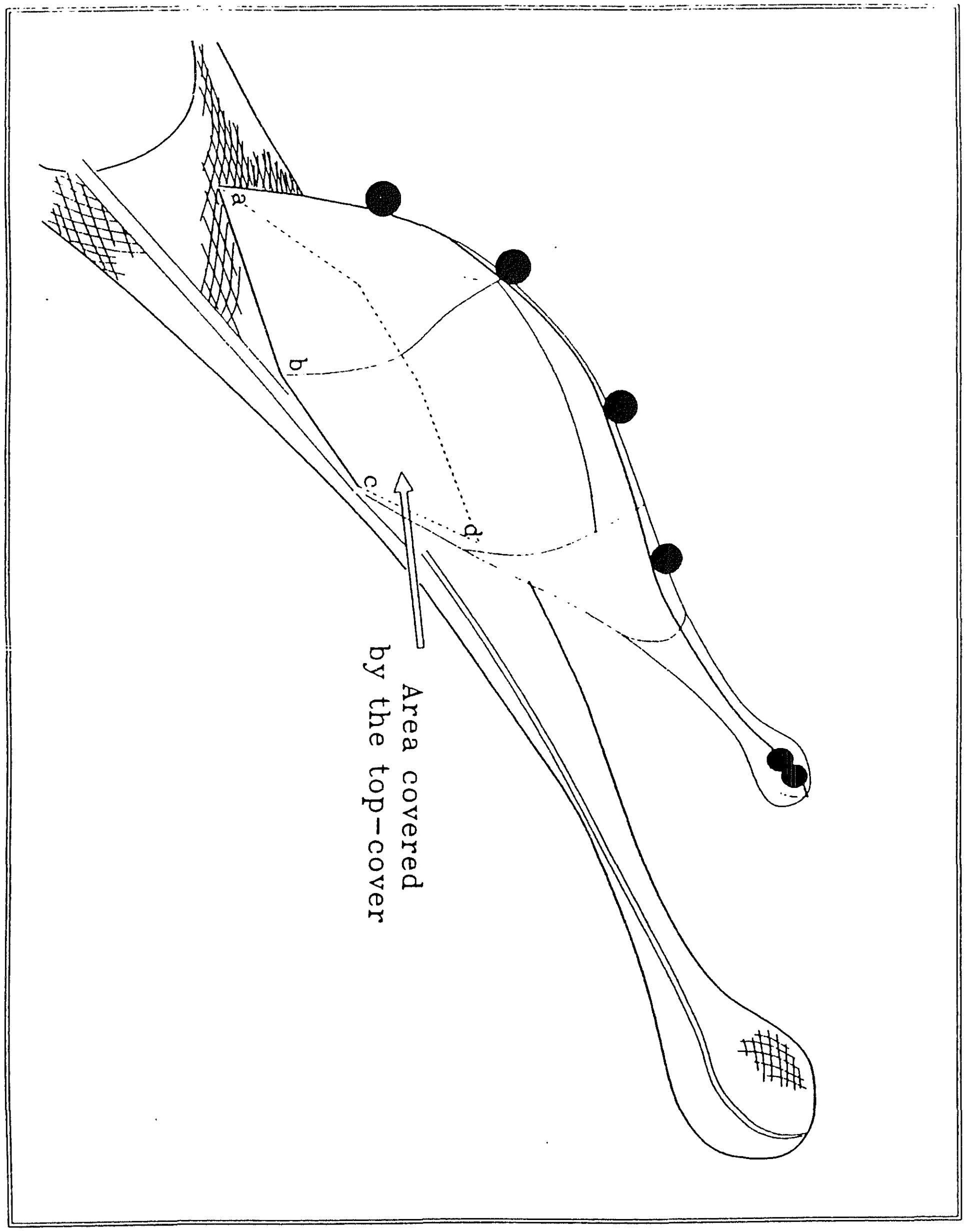
Snitt A-A Målestokk 1:1

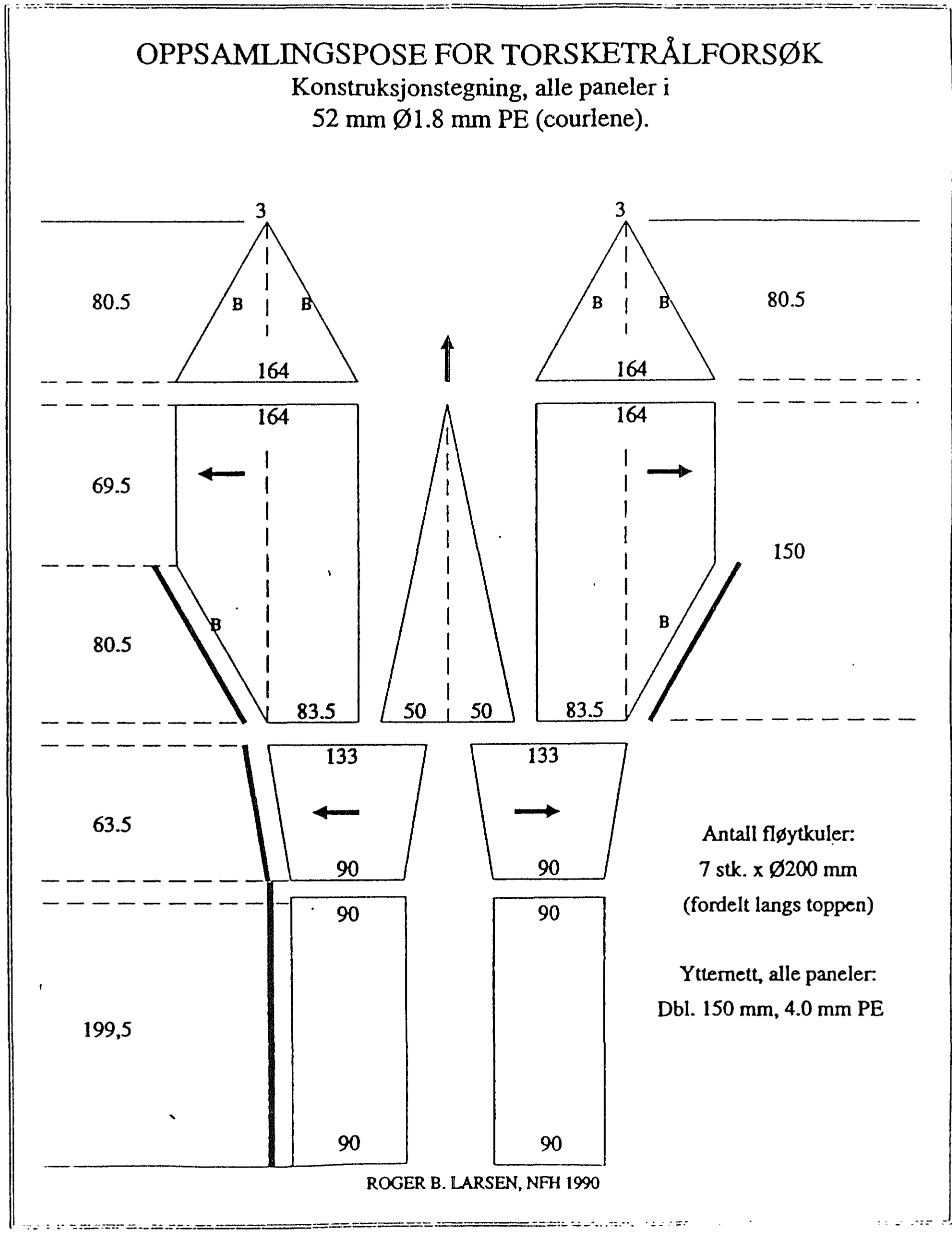
Pos nr.	Antall	Tittel	Dimensjon
6	7	Sylinderskruer	M12 × 25
5	7	Overklemme	30 × 8 × 65
4	7	Underklemme	30 × 8 × 118
3	7	Klemmer kompl.	30 × 8
2	6	Fester	Ø12
1	1	Ramme	Ø20 × 5429

Avd./Serie Dept./Series	Type Type	
Ref. Ref.	Sort-X	SELFI A/S Sort-X SELECTIVE FISHING TECHNOLOGY
Nr. No.	Cassette for replacing 1. Sorting grid	
Erstatter Replaces		

Erst. av Repl. by	Skala Scale	Konstr. Constr.	Godkj. Approv	Dato Date	Sign. Sign.
				20.05.93	J.E.M.

Fig 6 sect. 2.2.5





Figur 5: Konstruksjon av oppsamlingspose for seleksjonsforsøk.

Relative size distribution of Atlantic cod (Gadus morhua) during selectivity trials with 55 mm Sort-X. Barents Sea, September 1995.

Effect of codend mesh size (additional size selection)

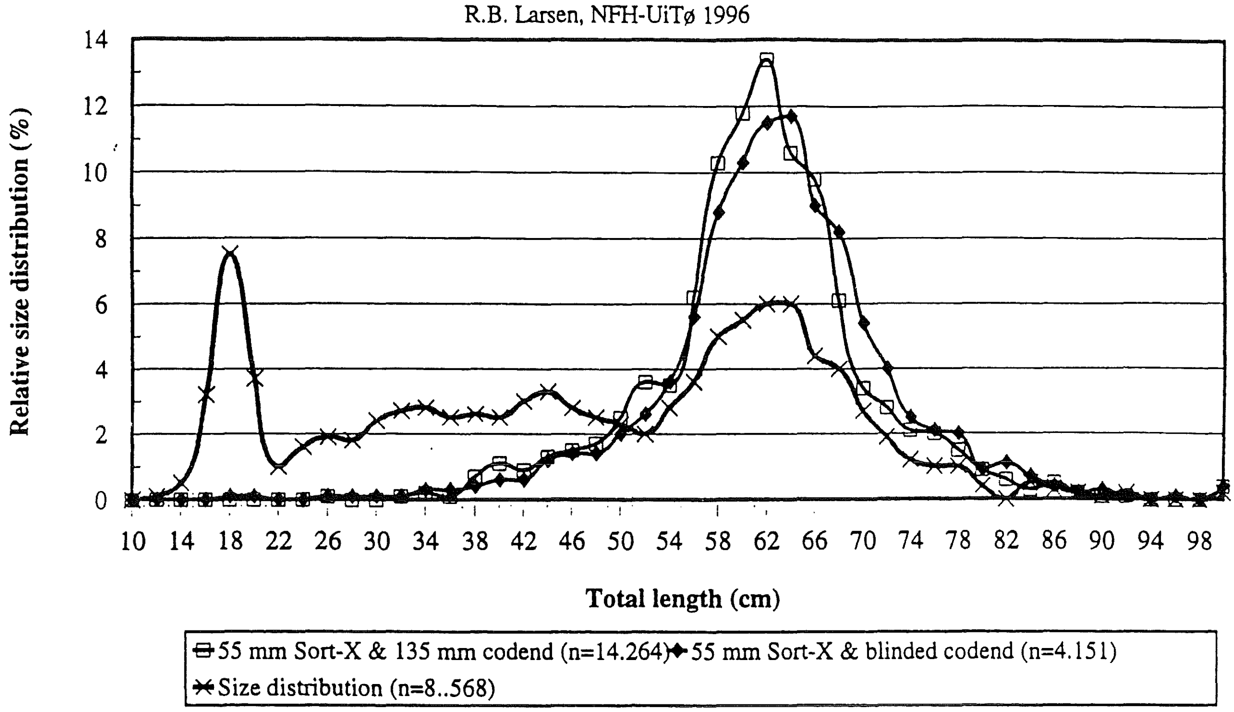


Fig. Relativ størrelsefordeling for torsk under forsøk med 55 mm Sort-X. Bjørnøya, September 1995.

Selection curves for Atlantic cod (*Gadus morhua*) during selectivity trials with varied bar distance of the Sort-X. Barents Sea, 1995 & 1996.

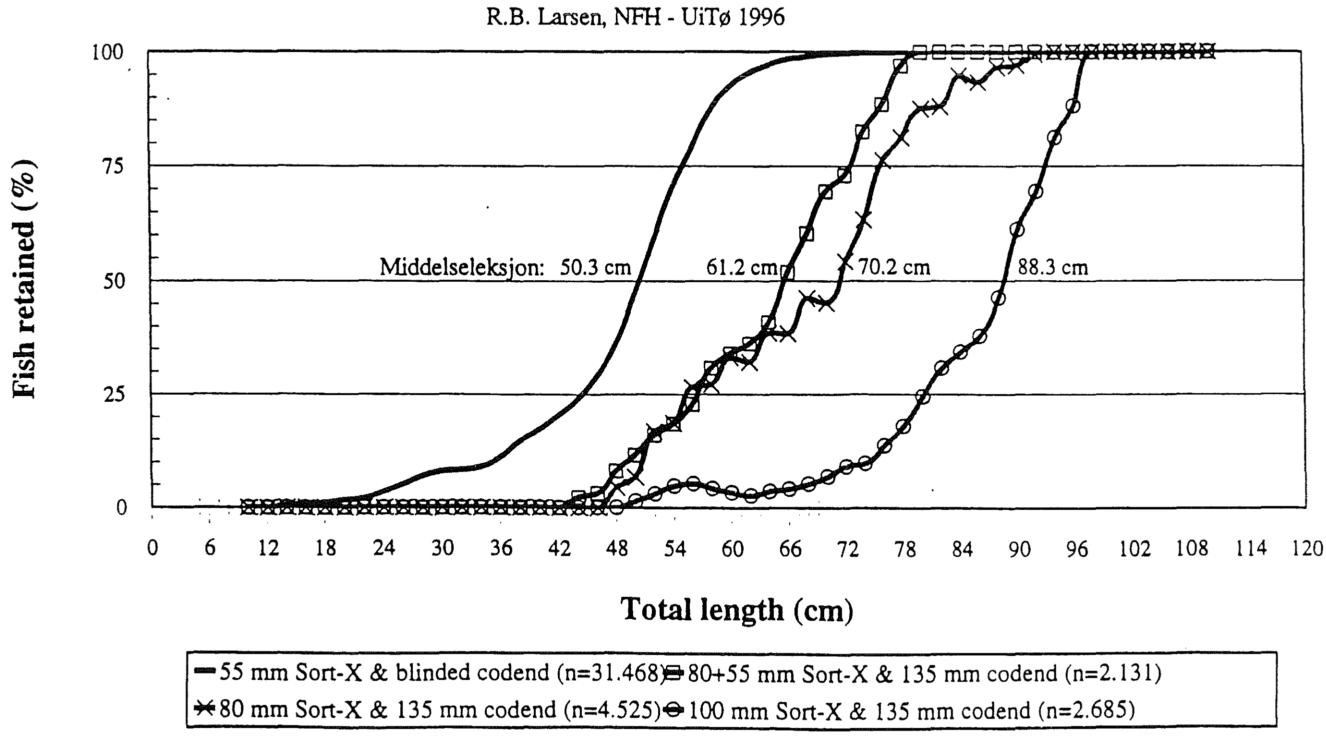


Fig. Seleksjonskurver for torsk under forsøk med ulik spileavstand i Sort-X. Barentshavet 1995 & 1996.

Selection curves for Atlantic cod (*Gadus morhua*) during selectivity trials with 55 mm Sort-X and russian Sort-V in a norwegian Alfredo 3 trawl. Barents Sea, September 1995.

R.B. Larsen, NFH - UiTø 1996

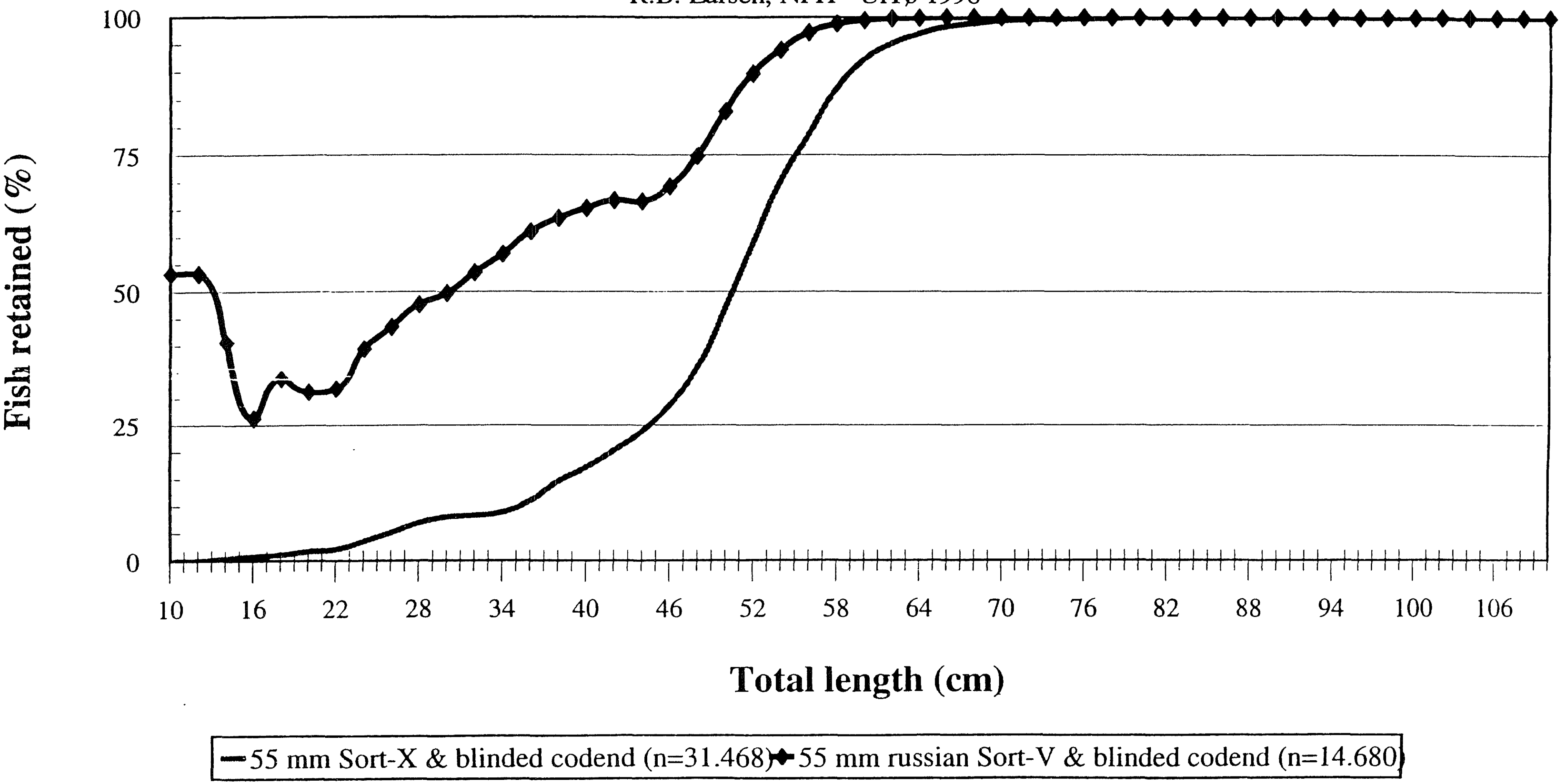


Fig. Seleksjonskurver for torsk under forsøk i norsk trål med 55 mm Sort-X og russisk 55 mm Sort-V. Bjørnøya, September 1995.

Selection for saithe (*Pollachius virens*) obtained by 50 mm Sort-X combined with a 100 mm codend. July/August 1994.

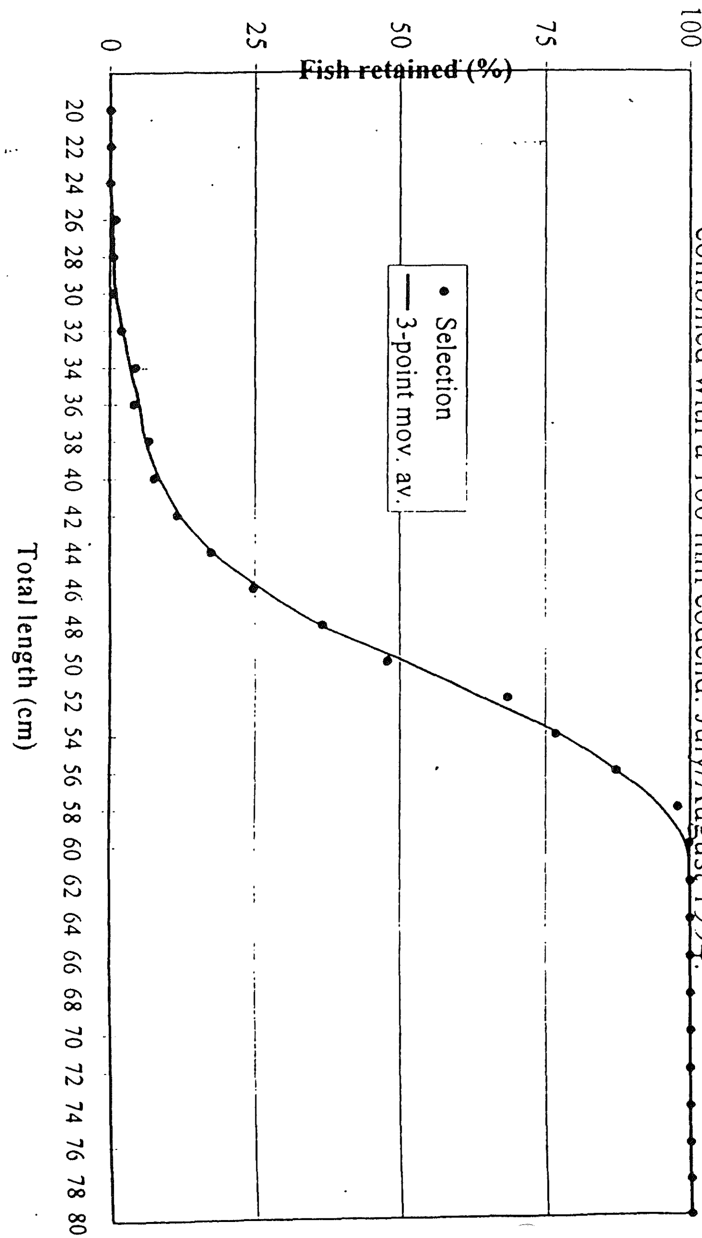
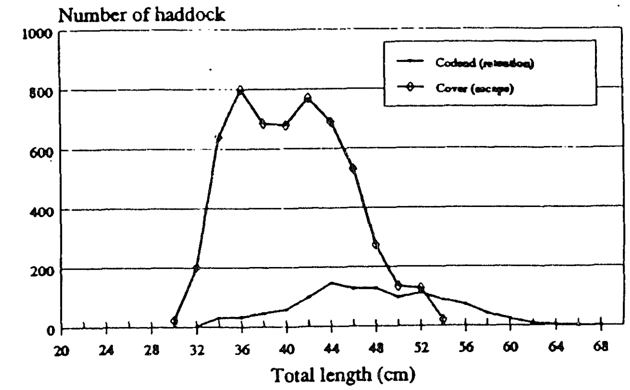


Fig. Seleksjonskurve for sei med 50 mm Sort-X kombinert med 100 mm sekk, Juli/August 1994.

Length-frequency distribution, haddock

55 mm Sort-X (Anny Krämer system)
Tested on the norwegian trawl



Selection curve for haddock

55 mm Sort-X + cover + codend blinder
2 hauls, July 1992

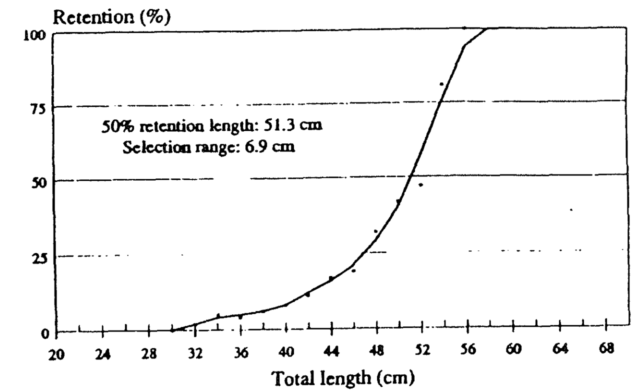


Figure 9. Haddock (Melanogrammus aeglefinus). Length-frequency distribution and selection curve obtained with the Sort-X system used on board "Poljarnoje Sijanije" during the joint experiments. The haddock experiment was made with a norwegian trawl on board "Anny Krämer" in the period 26-29 July 1992 along the Norwegian coast.

Selection curves for saithe (*Pollachius virens*) at different catchrates (kg's/hour) during hauls with 50 mm Sort-X and 100 mm codend.

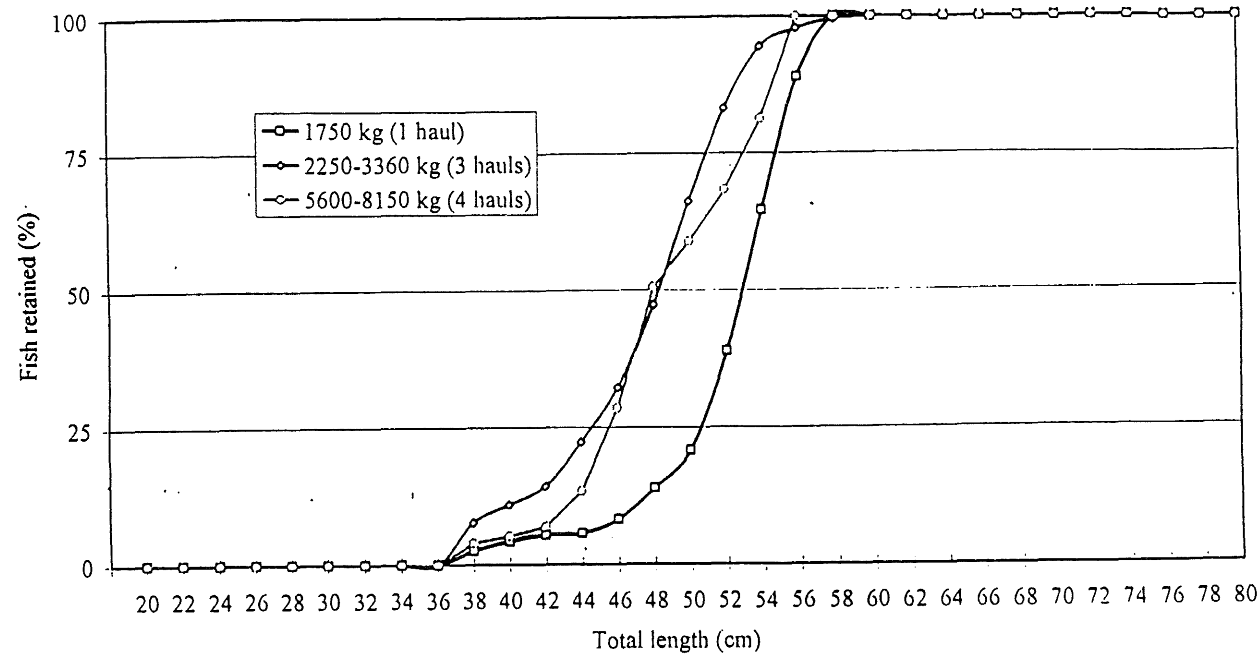


Fig. Seleksjonskurver for sei med 50 mm Sort-X kombinert med 100 mm sekk ved varierende fangstrater. Juli/august 1994, F/Tr. "Rosund".

The relative size distribution for saithe (*Pollachius virens*) during hauls with 50 mm Sort-X and 100 mm codend with cover (23 hauls) and without cover (12 hauls).

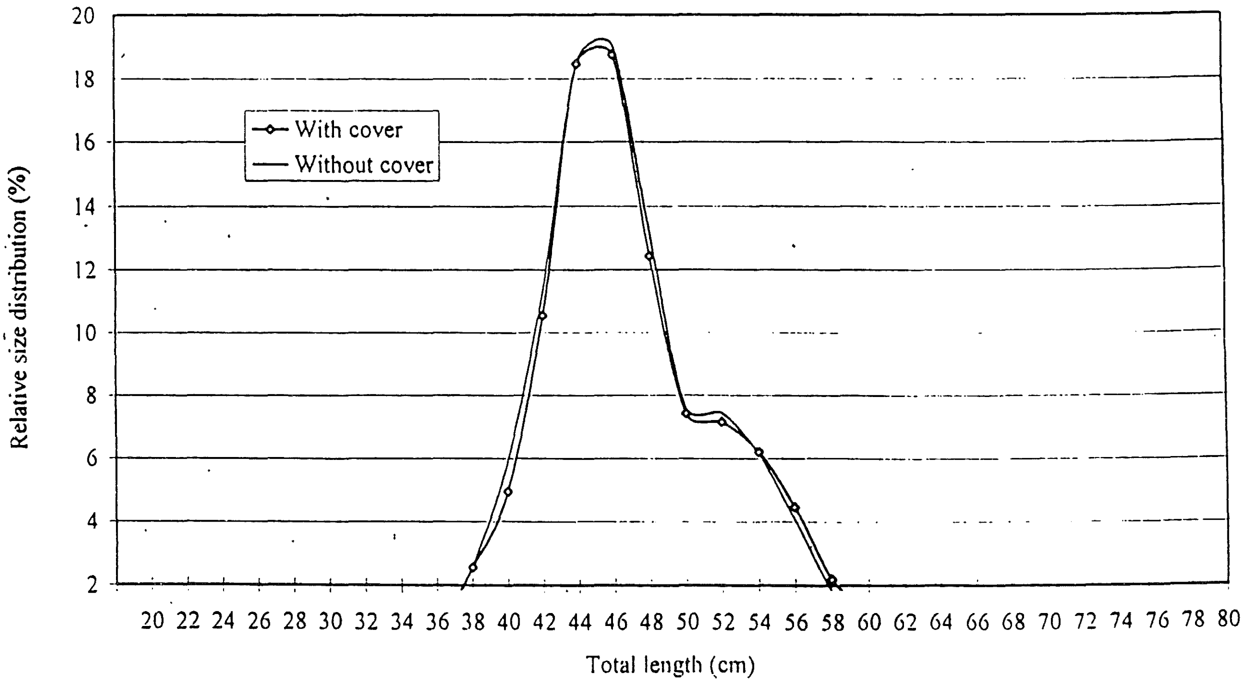


Fig. Relativ fangst-sammensetning på sei med 50 mm Sort-X kombinert med 100 mm sekk under hal med oppsamlingspose (23 hal) og uten oppsamlingspose (12 hal). Juli/august 1994, F/Tr. "Rosund".

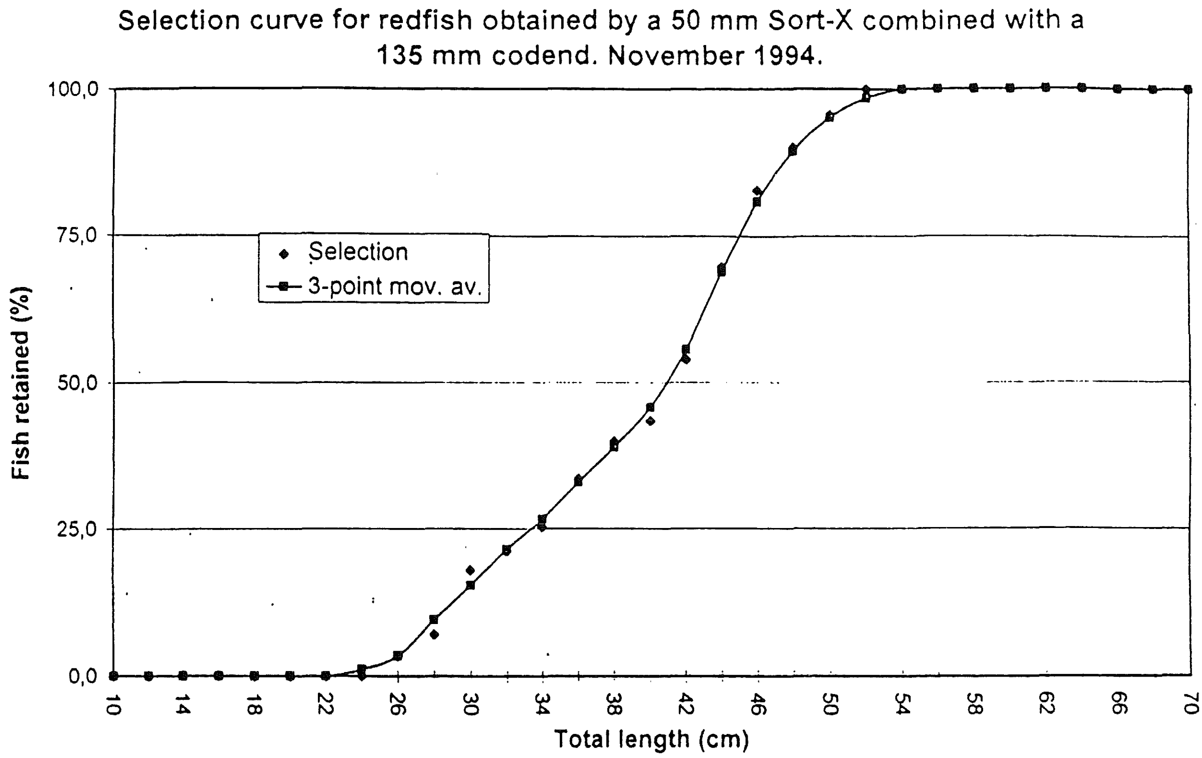
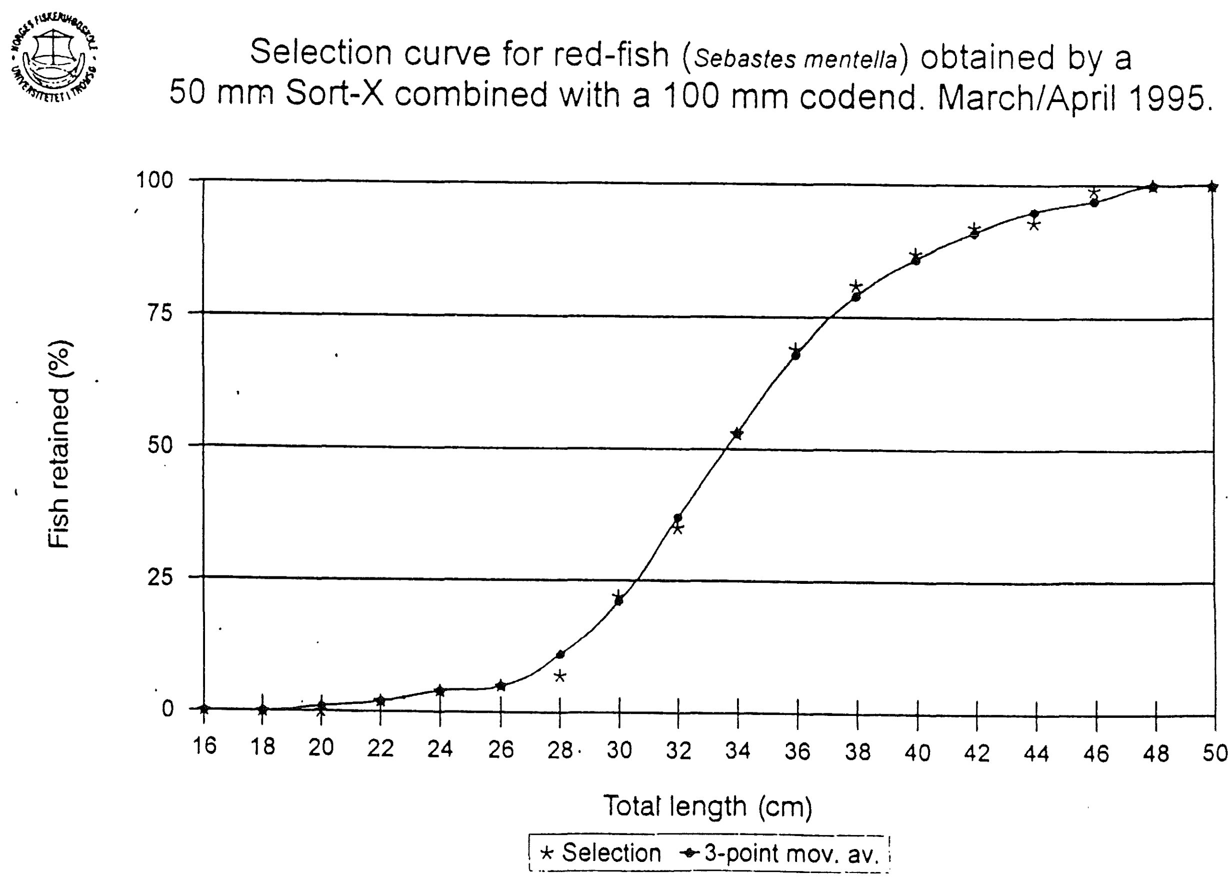


Fig. 3.22. Seleksjonskurve for uer med 50 mm Sort-X kombinert med 135 mm sekk. Fugløybanken-Tromsøflaket, november 1994 med F/Tr. "Hopen".



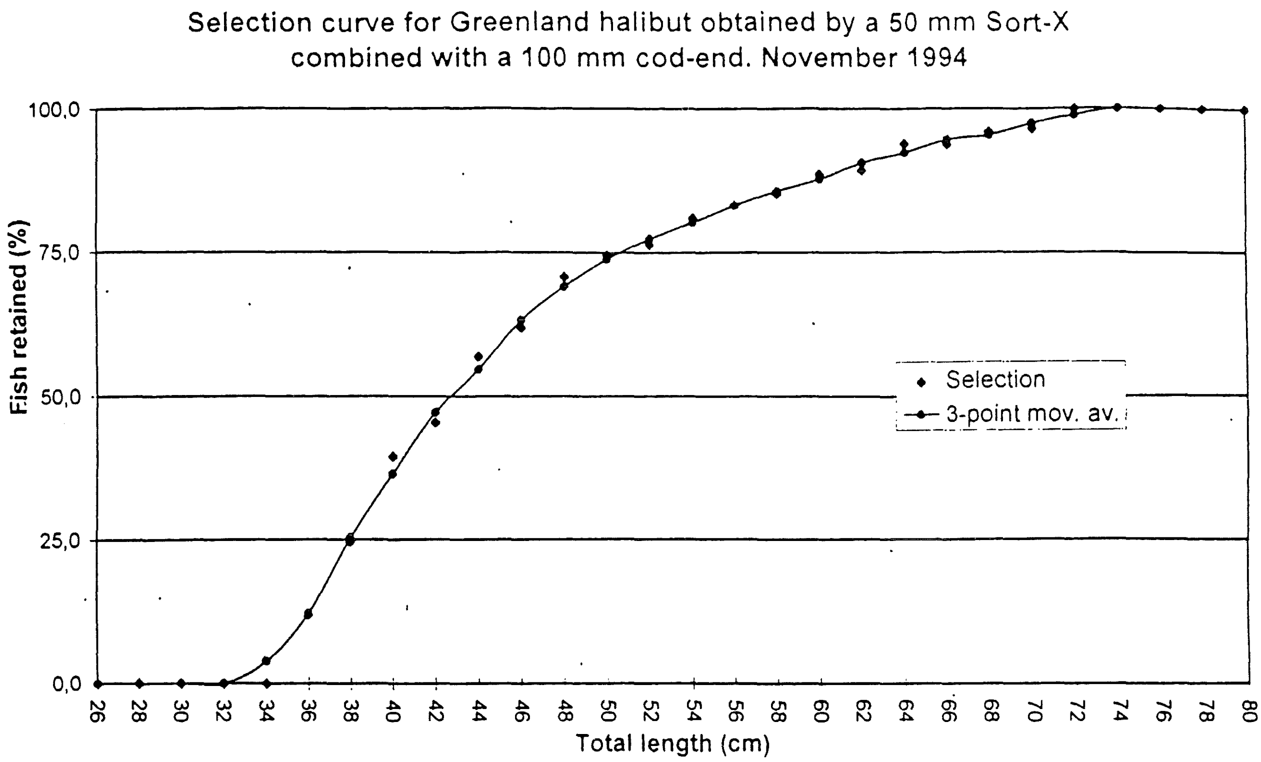


Fig. 3.2. Seleksjonskurve for blåkveite med 50 mm Sort-X kombinert med 100 mm sekk, november 1994.

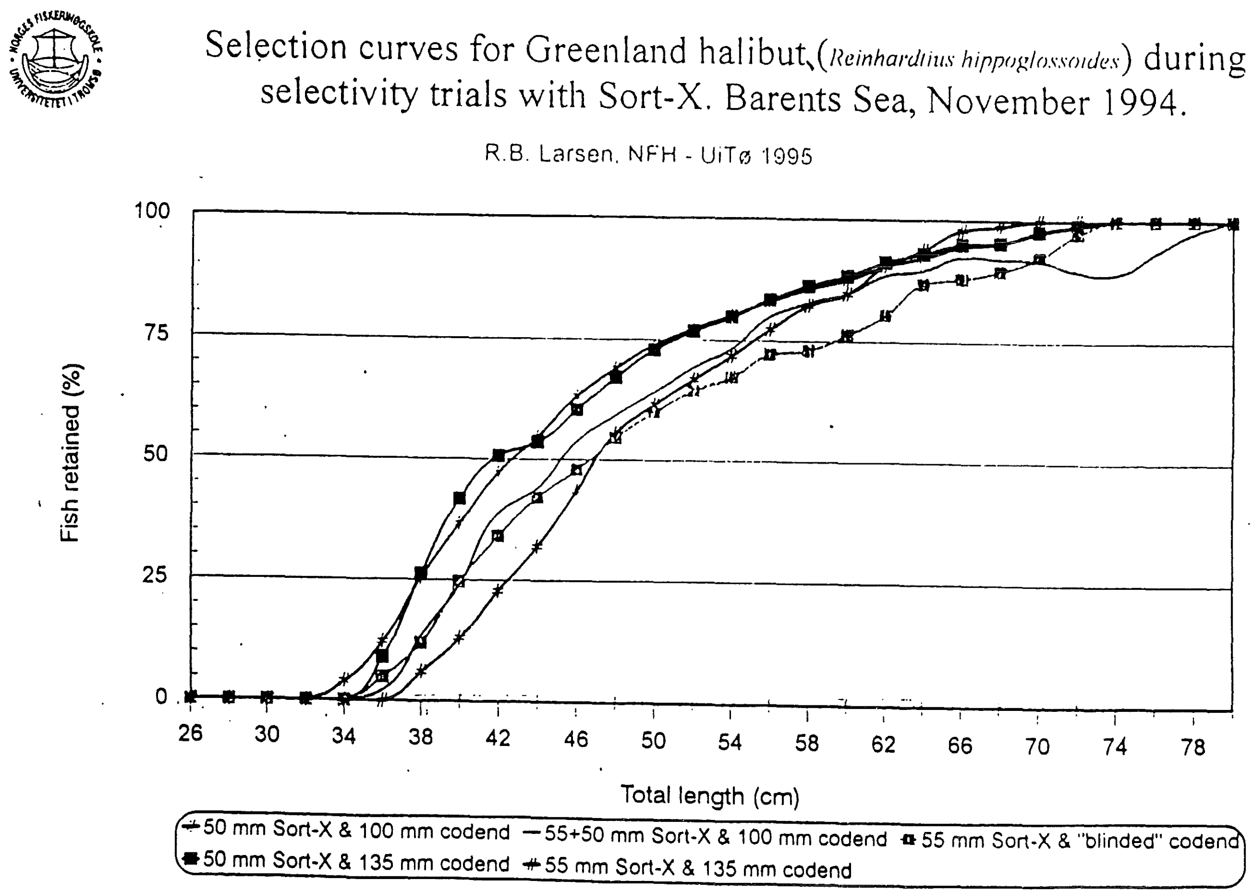


Fig. 3.11. Seleksjonskurver for blåkveite under forsøk med Sort-X, Fugløybanken-Tromsøflaket, nov. '94

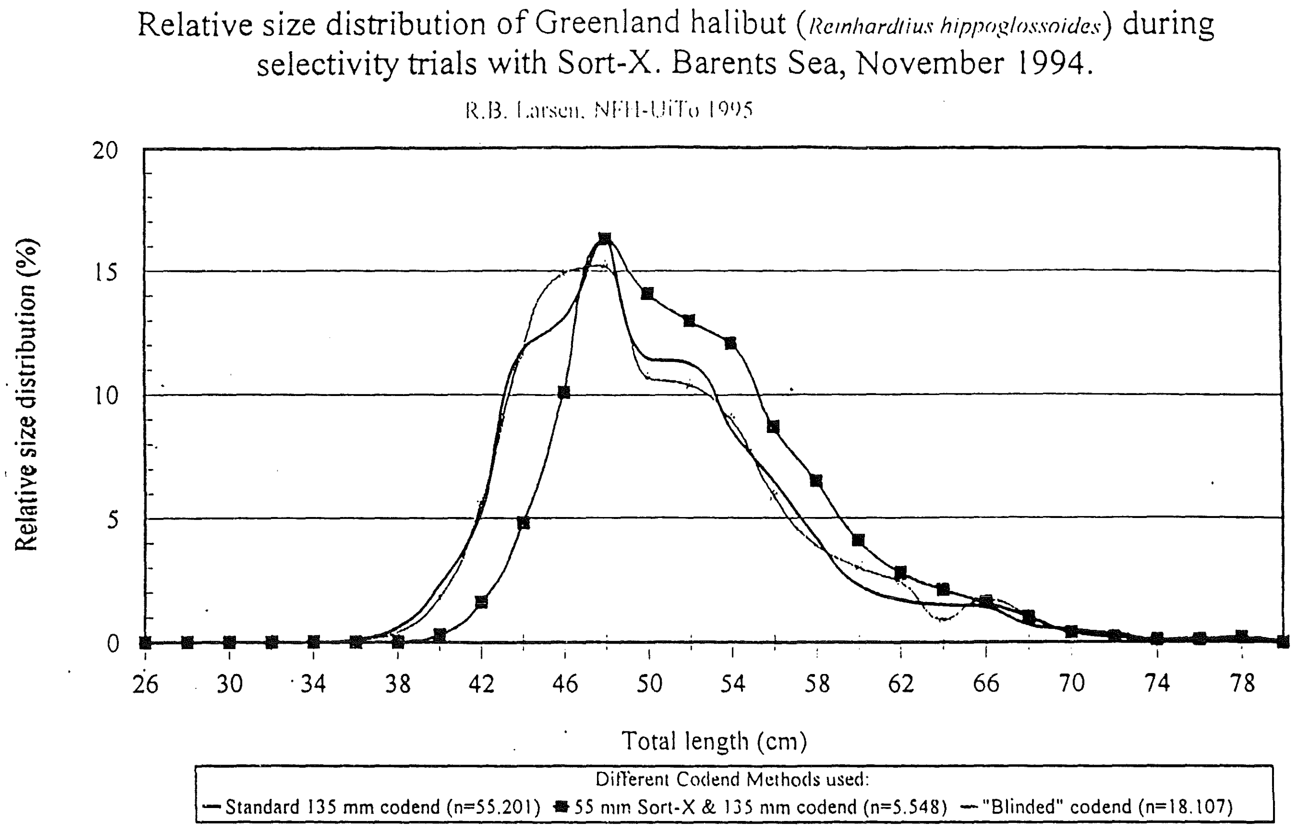


Fig. 3.16. Relativ størrelsefordeling for blåkveite under forsøk med Sort-X, Fugløybanken-Tromsøflaket, nov. '94

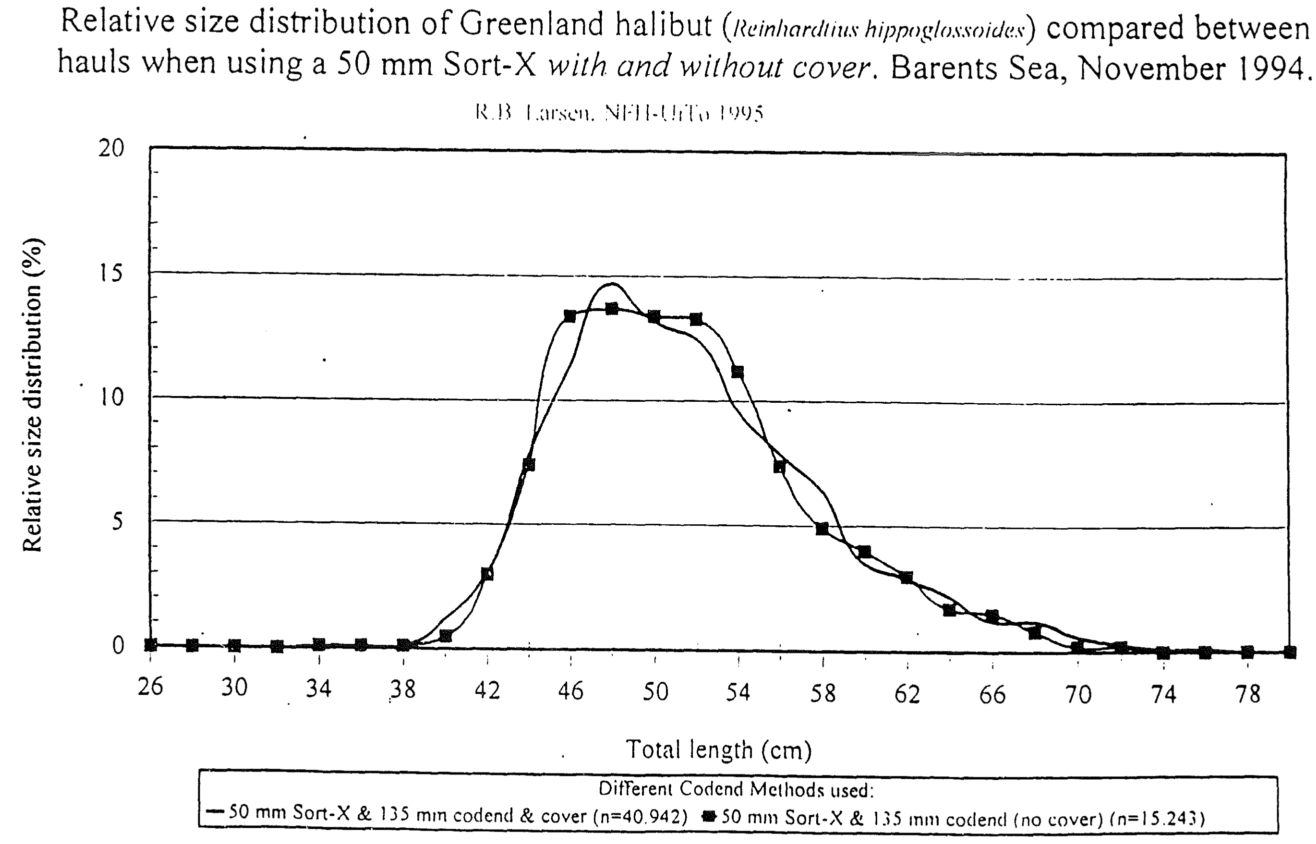


Fig. 3.18. Sammeligning av relativ størrelsefordeling for blåkveite under forsøk med 50 mm Sort-X & 135 mm sekk og med/uten oppsamlingspose. Fugløybanken-Tromsøflaket, nov. '94

APPENDIX V

Larsen, R.
Experiments with a new larger type of fish/shrimp separator grid with comparisons to the standard Nordmøre grid.

ICES FTFB W.G. Meeting, Woods Hole, USA, 15-18 April 1996

Experiments with a new, larger type of fish/ shrimp separator grid with comparisons to the standard Nordmöre grid

Roger B. Larsen

April 1996

The Norwegian College of Fishery Science -
University of Tromsö, N-9037 Tromsö, Norway

1. Introduction

The Nordmöre grid was developed in Norway during 1989/1990 (Isaksen et al. 1992), in order to reduce (or remove) bycatches of all sizes of fish and to avoid discarding of juvenile fish during the fishery for deep water shrimps (*Pandalus borealis*). It has since been successfully used by the whole international shrimpfleet fishing in the Barents Sea and fishing grounds along the Svalbard islands. The technique has been adopted by nations like Canada, Iceland, Faroe Islands, etc.

Since 1992 the norwegian off shore fleet has used grids made of stainless (18.12, acid proof quality) steel to match tensions in larger gears and to avoid corrosion, which occurs rather soon in grids made of aluminium (Larsen & Isaksen 1993). The sizes of grids used by (norwegian) vessels will vary with size and type of shrimp vessel, but for the last 3 years the off shore fleet has used a standard size which equals 1.5 m length and 1.3 m width. Any size of shrimp grid has been operated on an angle of attack between 50° and 45°. The bar distance is by regulation set to a *maximum* of 19.0 mm. Both the *length* of the grid and the bar distance was decided as a result of several experiments (Larsen et al. 1991). It was soon discovered that the combination between a relatively high angle of attack and a long grid would make it very troublesome to achieve effective results on the smallest fish (i.e. 0-group cod, haddock, etc.).

During the latest years the numbers of juvenile fish of important species like cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) has increased in the Barents Sea, and the numbers of 0-group fish retained by our shrimp trawlers has become a problem for the operation of this type of fishing gear. Since 1995 the *maximum* numbers of juvenile fish legally retained by shrimp trawls has been increased from 0.3 to 1.0 per kg shrimp-catch (Fisheries Directorate, announcement *J11-95*). Still, areas of the Barents Sea and Svalbard may be closed for all shrimp trawling during certain periods of the year (within the period of November to April). Alternative fishing grounds may be found, but normally with smaller shrimp catches and extremely low outcome for the fishermen. Several techniques have been tested to solve *this* bycatch-problem (Nordisk Råd 1996), but so far no acceptable results are achieved.

Based on the Nordmöre grid and ideas from Iceland and the Faroe Islands, a new and larger type of fish/shrimp separator grid (19.0 mm bar distance) was tested during a cruise along Svalbard in July/August 1995 (Maurstad and Larsen 1995). The basic idea of the new consept was to use a longer grid and a lower angle of attack compared to the Nordmöre version (i.e. 45°, 35°, 30° and 25° angle of attack for the new grid) in order to achieve:

a) Improved escapement of juvenile fish (i.e. 0-group cod, haddock, etc.)
b) More effective escapement of typical bycatch species like redfish (*Sebastes spp.*), various types of flatfish (Greenland halibut, Long rough dab, etc.) and easier release of debris.
c) Maintain a low and acceptable loss of shrimps (comparable to the Nordmöre grid).

2. Materials and Methods.

The trials were made along the western (N80°00'-E10°15') and northern (N80°30'-E16°00') coast of Svalbard in the period 22. January to 4. February 1996, on typical shrimp grounds 400-500 m of depth. During this time of the year the area has a 24 hour darkness, temperatures of -10 to -30 C° , often strong winds and vessels will most of the time operate in drift ice.

The experiments were made on board the R/V "Jan Mayen" (University of Tromsö), which is a 64 m ice-strengthened stern trawler originally built as a shrimp factory vessel (Danyard 1988). The vessel is equipped with 40 tonnes trawl winches and ice gallows and she is powered with a 4080 Bhp (3000 kW) Wärtsilä Vasa main engine.

During the experiments a standard 2800 mesh (x 40 mm) "Egersund Low Polar" (fishing line: 59.60 m) trawl was used, equipped with a 24" steel bobbin gear, 40 m double bridles and a pair of 2.500 kg's Morgére-R otter boards. The trawl geometry was monitored by Scanmar spread and height sensors (on a RU-400 cabinet). Towing times varied between 3 and 4 hours at a towing speed of 3.0-3.3 knots.

The installation of the new type of grid is similar to the standard Nordmöre grid (Fig. 1), but the construction differs in the length of the grid and the way the crosswise strengthening bolts are fastened to the lengthwise bars (Fig. 2). The large grid was installed into a 2x300 mesh tubular nylon (PA) section (42 mm mesh size) with a 1.8 mm courlene (PE) guiding funnel. On the standard separatotr grid (Nordmöre version), the distance between the opening of the leader funnel on the grid is 50 cm, and the aft opening of the leader funnel is normally 30 cm in height. With the new, large grid the distance between leader funnel and the grid was 100 cm (hauls 1-8, 16) and 150 cm (hauls 17-18). The new, large grid has a weight of 95.5 kg, and neutral buoyancy was achieved with 38 plastic floats (Ø200 mm/8"). The large grid was tested at two different angles of attack (theoretical, and according to installation); **18°** and **23°** (Fig. 3), whilst the standard Nordmöre grid was tested at 48°, which is the normal angle of attack (theoretical) for this grid. A small meshed top-cover (Fig. 4) was used to retain escaping fish and lost shrimps. A Scanmar grid sensor was used to monitor grid angle and waterflow through the grid.

3. Results

Data from only two hauls are treated in this presentation, i.e. hauls 8 (large grid at an angle of 18°) and 13 (standard Nordmöre at an angle of 48°). As a general impression, fish seems to escape more easily with the new, large grid compared to the standard Nordmöre grid. During the comparisons between the two grid-types, the average loss of shrimps (by weight) was considerable smaller with the large grid than with the Nordmöre (ref. Table 2) despite the large difference in angles of attack.

From a practical point of view, the large grid is very easy to handle on board a big stern trawler. Due to low angle of attack of the large grid the problems seen with the Nordmöre grid during shooting and towing with twist in the section in front of the grid, seems to be solved. The large grid is more stable with respect to grid-angle than the standard grid (Fig. 3.1), which tends to loose its high angle when a certain catch-size is reached. During the last towing hour, the angle of the Nordmöre grid changed from 46-38°. Another major difference between the two grid-types seen during the experiments, was the waterflow through the grids. In the standard grid the waterflow falls to less than 0.5 knots after a few minutes, while the waterflow through the large grid was very high during the whole towing (Fig. 3.2).

The sorting effects with the two grid types for the most numerous species of fish, are shown in Fig's 3.3-3.6. The results are given as selection curves smoothed by 3-point moving averages. For all species (cod, red-fish, Greenland halibut and Long rough dab) the best results are obtained with the new, large shrimp seprator grid.

4. Discussion

The informations gathered during January-February 1996 supports the conclusions of an earlier experiment with the large grid (Maurstad & Larsen 1995), i.e. the new type of grid is working generally better than the standard type of grid (Nordmöre grid). During comparisons between the two grid types, it was obvious that fish/shrimps were blocking the bars of the standard grid (low water flow through it), which partly explains the large loss of shrimps. No such problems arose with the large grid. Another explanation to the relative high loss of shrimps by the standard grid, is the reduced angle of attack during the last part of the hauls (as the shrimp-catch increases in the codend). Previous experiments with the standard Nordmöre grid have, however, revealed shrimp losses of 1-3% by average (Isaksen et al. 1992, Larsen & Isaksen 1993). With the large grid, the avarege loss of shrimp was smaller and the grid is more stable with respect to angle of attack. No more than 6.2% of the shrimp catch (by weight) was lost during haul 7 with the aft part of the leader funnel open and with a distance between funnel and grid of 1.0 m.

The numbers of juvenile fish during this experiment were too high with both types of grids, but the results are best for the large grid. Even at an extreme low angle of attack (18°), the numbers of small fish (mainly 0- and I-group fish smaller than 17-19 cm total length), retained by the shrimp trawl in most cases exceeded the legal limit of 1 juvenile/kg shrimp catch. If the waterflow through the large (really) is as high as measured during our experiments, the low sorting effect on the smallest fish may be explained due to low swimming ability of these fishes. It is therefore necessary to encourage work that can solve the bycatch problem of the smallest fish in the northern shrimp fisheries. Area-closure seems to be an effective tool with respect to fish-conservation and in protecting the juvenile fish, but such regulations may be very severe to the fishermen.

Acknowledgements

The crews on board R/V "Jan Mayen" were very helpful in solving practical details of the work, and I'm grateful to my staff of scientific assistants Kjell Gamst, Magnus Hafsteinsson, Bernt Bertelsen and Tormod Jensvoll for their solid and important work during the cruise. Teacher Atle Skutvik and students of Kvaløya high school are thanks due for their assistance during all the boring sorting and registration work.

References

Isaksen, B., Valdemarsen, J.W., Larsen, R.B. & Karlsen, L. 1992. Reduction of fish by-catch in shrimp trawl using a rigid separator grid in the aft belly. Fish. Res., 13: 335-352.

Larsen, R.B. & Isaksen, B. 1993. Utprøving av Nordmørsrist i reketrål på fiskefeltene vest og nord av Svalbard. Norges fiskerihøgskole, Universitetet i Tromsø. 52 pp.

Larsen, R.B., Karlsen, L., Isaksen, B. & Valdemarsen, J.W. 1991. Beskrivelser av utarbeidelse & montering og praktisk bruk av "Nordmørsrista" - sorteringsrist i reketrål. Fiskeridirektoratet i Bergen. 26 pp.

Nordisk Råd 1996. Seleksjon i reketrål (Ed.: J.W. Valdemarsen). TemaNord 1996:520.

Maurstad, E. & Larsen, R.B. 1995. Utprøving av ny og større "Nordmørsrist" i reketrål. Norges fiskerihøgskole, Universitetet i Tromsø. 38 pp.

Table 1: Trawl data, sorting-systems & arrangements and comments for haul made along Svalbard during trials with a 2800# shrimp trawl with seprator grids on board the R/V "Jan Mayen" in the period 22 January - 4 February 1996.

Haul nr.	Date	Position	Depths (m)	Towing time	Shrimp catch/ towing hour	Sorting system	Comments
1	25.01.96	N80.01'-E10.27'	460-483	01.10-05.10	143 kg	Large grid, 18°	No cover, open leader- funnel, 1.0 m funnel distance
2	25.01.96	N80.03'-E10.26'	490-441	09.05-13.00	156 kg	Large grid, 18°	Cover, open funnel, 1.0 m funnel distance to grid
3	25.01.96	N80.10'-E10.32	479-485	14.10-18.10	237 kg	Large grid, 18°	Cover, 2 Greenland sharks, 1 large tyre
4	25.01.96	N80.02'-E10.32'	498-495	19.30-23.35	224 kg	Large grid, 18°	Cover, 30 cm opening in leader funnel
5	26.01.96	N80.10'-E10.33'	499-487	00.45-4.15	217 kg	Large grid, 18°	Same arrangement as under haul 4
6	26.01.96	N80.25'-E16.01'	407-376	11.30-14.30	789 kg	Large grid, 18°	Same arrangement as under haul 4
7	26.01.96	N80.29'-E16.03'	390-420	15.30-17.00	637 kg	Large grid, 18°	Cover, open leader funnel, 1.0 m funnel distance
8	26.01.96	N80.21'-16.10'	396-482	18.15-21.30	584 kg	Large grid, 18°	As haul 7, 2 large Greenland sharks, some stone
9	27.01.96	N80.31'-E15.39'	330-320	04.55-08.55	288 kg	Nordmöre grid	No cover, normal arrangement, grid angle 47-41°
10	27.01.96	N80.27'-E15.57'	390-380	10.20-13.20	721 kg	Nordmöre grid	As haul 9, grid angle 48-39°
11	27.01.96	N80.22'-E16.15'	405-386	14.15-18.15	523 kg	Nordmöre grid	As haul 9, grid angle 46-36°
13	27.01.96	N80.27'-E15.51'	355-352	23.40-03.40	505 kg	Nordmöre grid	Cover, grid angle 46-38°, 8.8% shrimp lost
14	28.01.96	N80.25'-E15.50'	350-355	04.35-08.35	628 kg	Nordmöre grid	Cover, grid angle 48-38°, 1 Greenland shark
15	28.01.96	N80.28'-E15.46'	350-287	10.25-14.20	389 kg	Nordmöre grid	Cover, grid angle 49-42°, 2.7% shrimp lost
16	28.01.96	N80.25'-E15.54'	378-435	22.15-02.15	621 kg	Large grid, 23°	No cover, angle 26-22°, 1.0 m funnel distance
17	29.01.96	N80.21'-E16.17'	406-379	04.15-07.30	658 kg	Large grid, 23°	No cover, angle 26-23°, **1.5** m funnel distance
18	29.01.96	N80.22'-E15.58'	308-351	11.40-13.10	613 kg	Large grid, 23°	No cover, angle 26-24°, 1.5 m funnel distance, camera on grid sectio

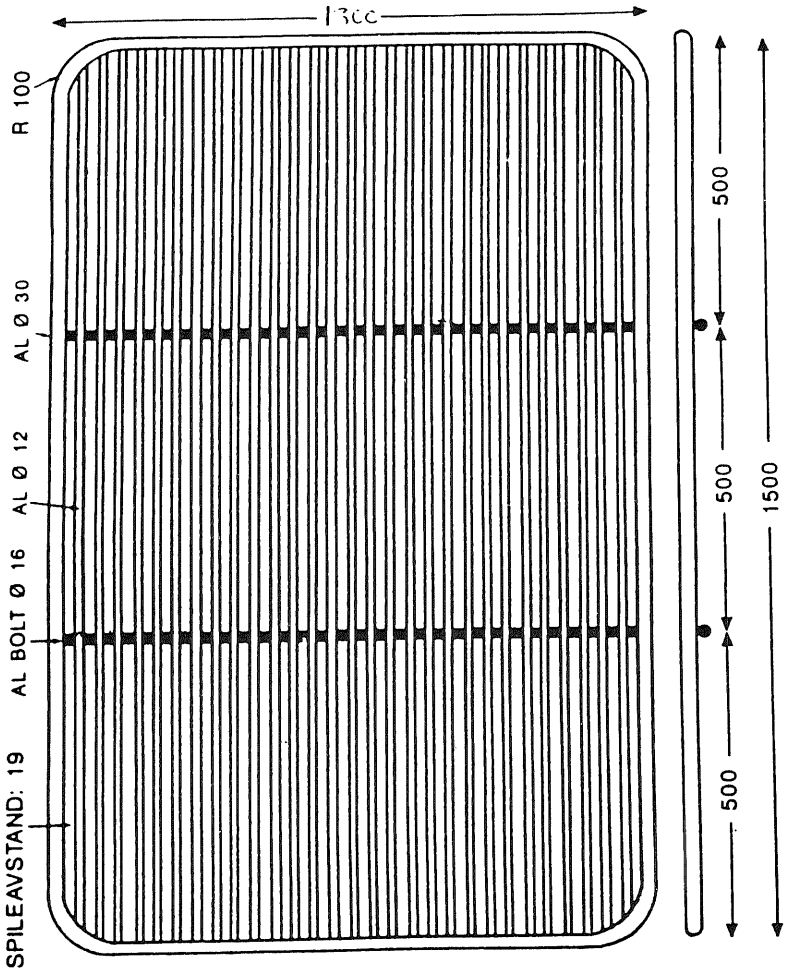
Table 2: Catches made during experiments with the **2.5 m** long shrimp/fish separator grid at **18°** angle of attack on board the R/V "Jan Mayen" along Svalbard islands, 22 January - 4 February 1996. Shrimp catches are given as kg's, while fish-catches are given by numbers. Data from hauls with smallmeshed cover to retain escapees.

Haul nr., codend/cover	**Shrimps, kg's**	**Cod**	**Redfish**	**Greenland halibut**	**Long rough dab**	**Polar cod**	**Other species, kg's**	**Fish total, kg's**	**% Shrimp lost (by weight)**
2: Codend	590.0	737	1.449	0	369	870	2.8	54.3	3.5%
2: Cover	21.1	667	6.121	0	1.407	661	48.9	768.6	
3: Codend	920.0	723	367	0	170	659	2.6	38.2	3.1%
3: Cover	29.3	296	845	91	845	313	50.7	291.8	
4: Codend	874.0	995	313	0	111	783	2.1	37.0	2.2%
4: Cover	20.0	672	1.657	61	261	334	33.0	344.7	
5: Codend	736.0	1.244	851	0	144	275	1.4	47.6	3.3%
5: Cover	25.3	679	2.079	51	269	124	32.6	350.7	
6: Codend	2.254.0	5.483	2.745	21	268	3.765	3.0	105.5	4.8%
6: Cover	112.5	1.084	2.314	163	679	186	12.7	420.7	
7: Codend	897.0	2.657	1.099	14	209	269	2.44	56.3	6.2%
7: Cover	59.2	1.313	1.072	114	393	97	8.5	212.8	
8: Codend	1.840.0	2.162	870	95	175	-	4.8	56.9	3.1%
8: Cover	57.9	484	448	404	448	-	9.6	191.0	

Table 3: Catches made during experiments with the **standard** (1.5 m long Nordmöre) shrimp/fish separator grid at **48°** angle of attack on board the R/V "Jan Mayen" along Svalbard islands, 22 January - 4 February 1996. Shrimp catches are given as kg's, while fish-catches are given by numbers. Data from hauls with smallmeshed cover to retain escapees.

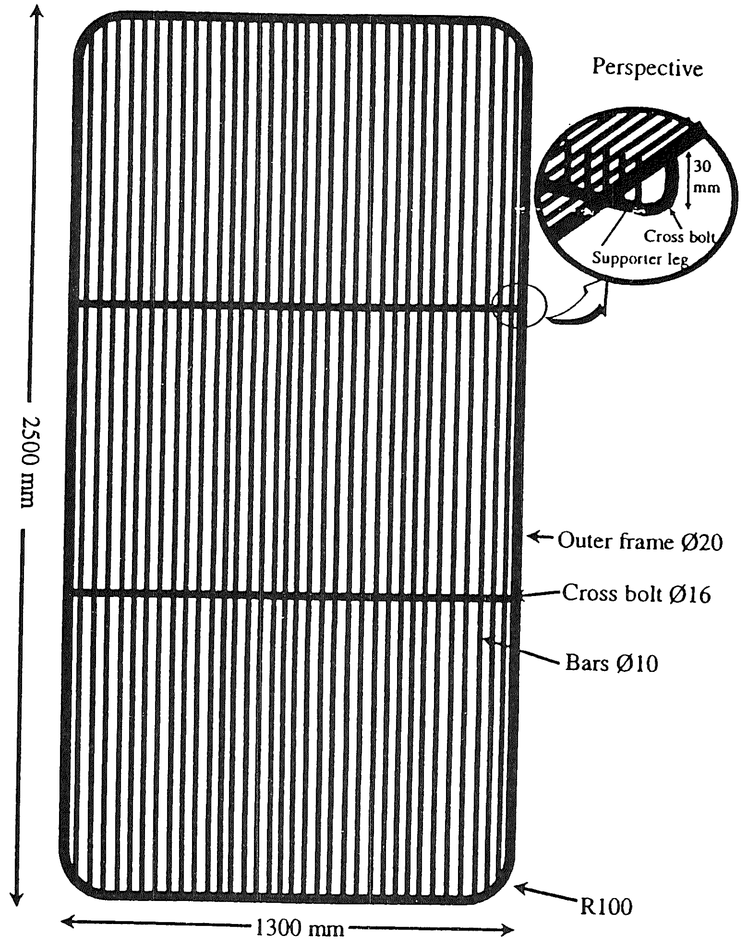
Haul nr., codend/cover	Shrimps, kg's	Cod	Redfish	Greenland halibut	Long rough dab	Polar cod	**Other species, kg's**	**Fish total, kg's**	**% Shrimp lost (by weight)**
13: Codend	1.840.0	3.027	2.563	36	401	1.780	4.3	99.1	8.8%
13: Cover	178.0	465	961	84	678	596	16.6	205.2	
14: Codend	2.326.0	7.836	3.868	42	2.015	624	7.5	157.9	7.4%
14: Cover	184.5	1.554	3.338	172	978	231	17.9	521.1	
15: Codend	1.518.0	3.256	2.119	57	532	6.823	8.9	144.0	2.7%
15: Cover	42.8	353	818	73	500	1.169	11.3	194.9	

NORDMØRSRISTA - HAVREKETRÅL
ALUMINIUM



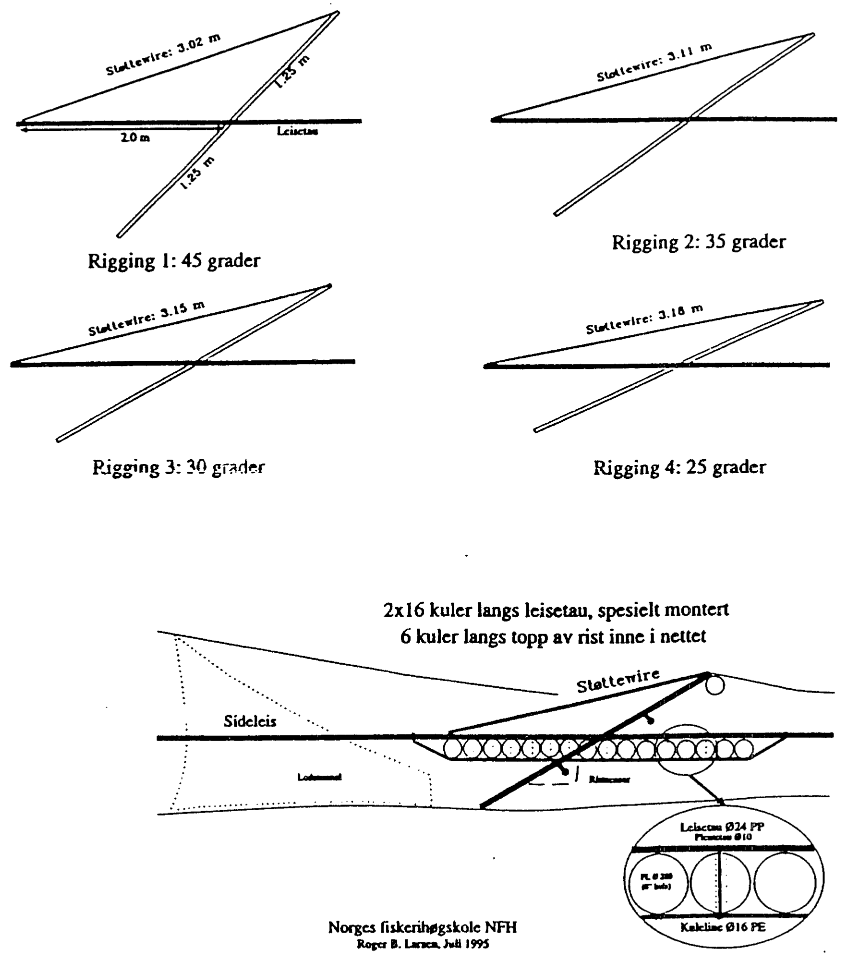
Figur · Konstruksjonstegning av sorteringsrist for havreketrål, sammensatt av aluminiums-moduler. Hoveddimensjoner på rista er 978 x 1500 mm, men større rist<u>bredde</u> er mulig.

New type of separator grid for shrimp trawls - 1995
1300 x 2500 mm (3.25 kv.m.)
High quality stainless steel 18.12
19.0 mm bar distance



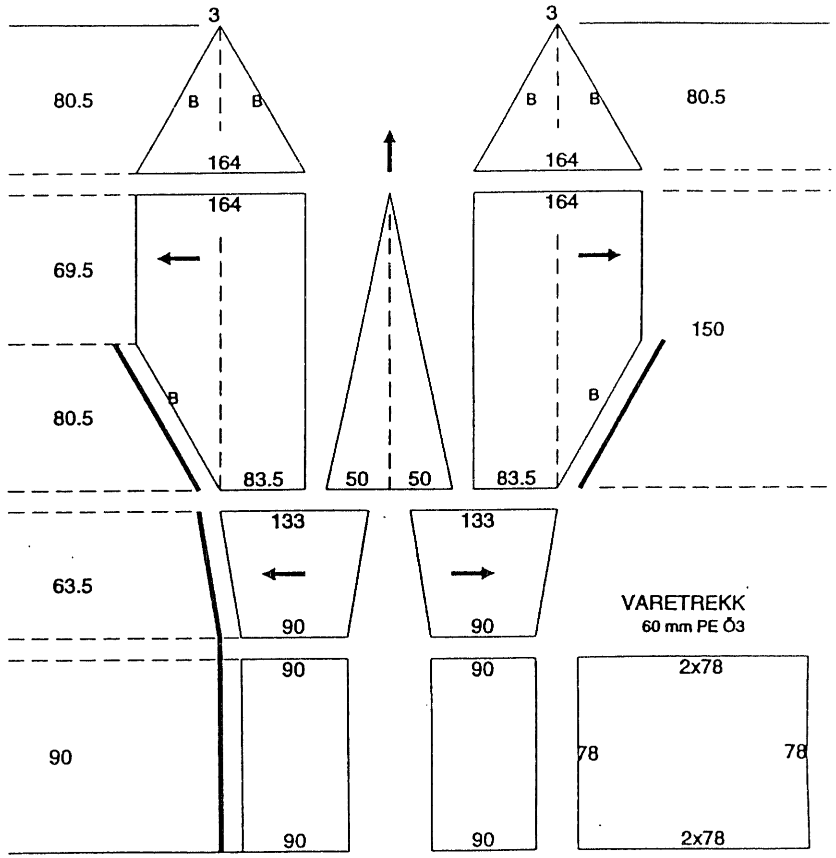
Roger B. Larsen,
NFH - UiTø 1995

Innmontering av ny type Nordmørsrist under forsøkene 26. juli - 4. august 1995



OPPSAMLINGSPOSE FOR REKETRÅLFORSØK

Konstruksjonstegning, alle paneler i
38 mm Ø1.8 mm PE (courlene).



ROGER B. LARSEN, NFH 1990

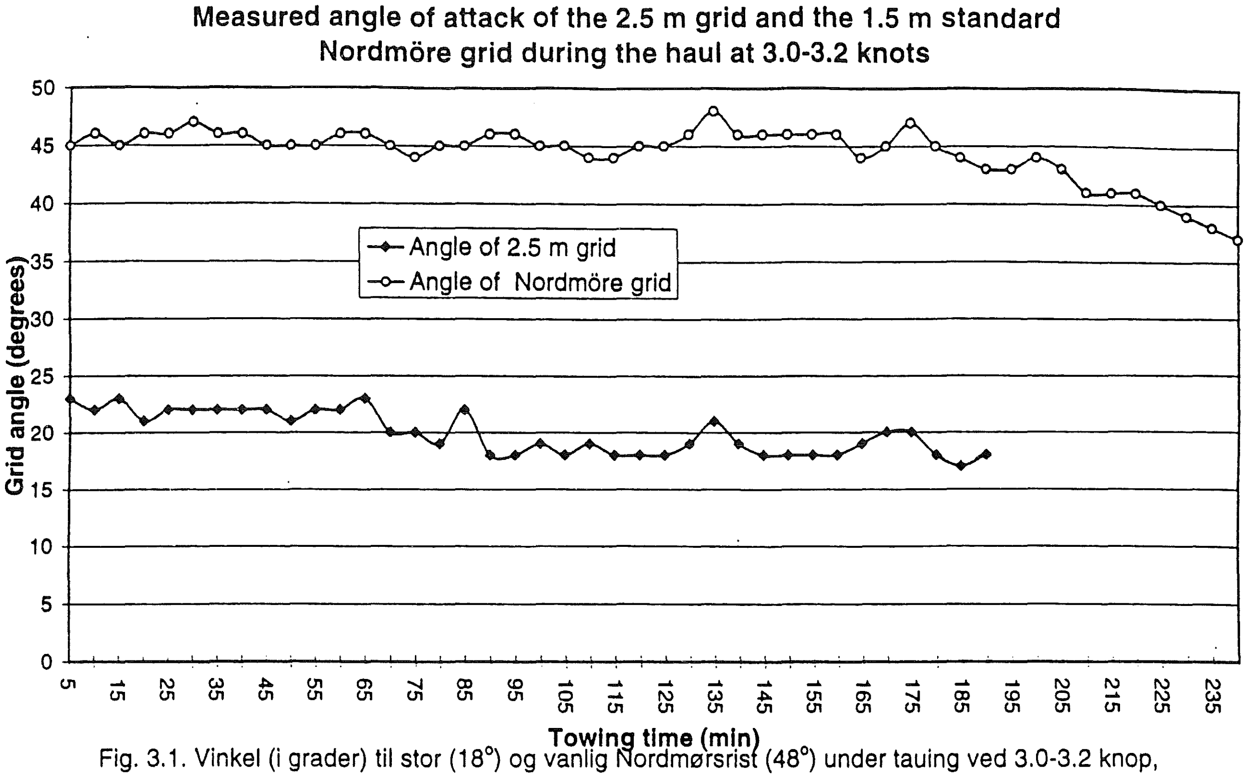


Fig. 3.1. Vinkel (i grader) til stor (18°) og vanlig Nordmørsrist (48°) under tauing ved 3.0-3.2 knop, Svalbard januar-februar 1996.

R.B. Larsen, NFH -UiTø 1996

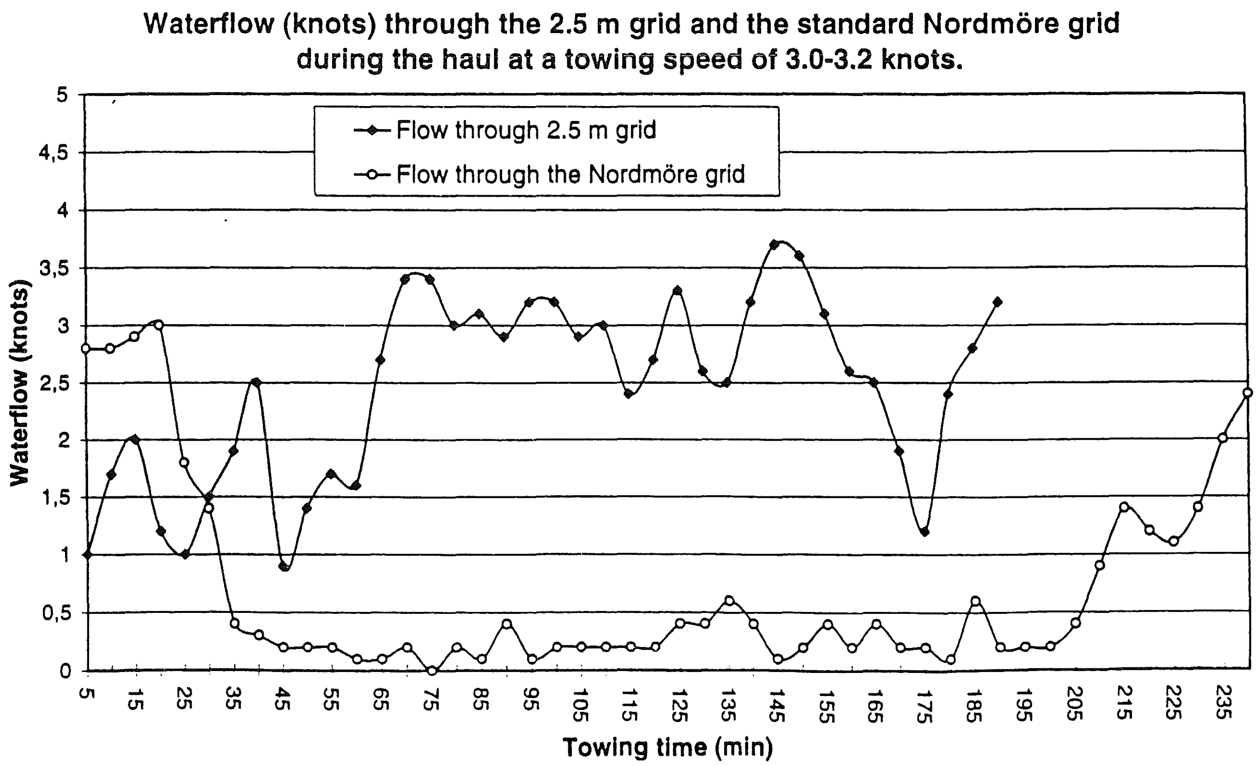


Fig. 3.2. Vannstrøm (i knop) gjennom stor og vanlig Nordmørsrist under tauing ved 3.0-3.2 knop, Svalbard januar-februar 1996.

Sorting effect on cod (*Gadus morhua*) with the new 2.5 m grid and the standard 1.5 m Nordmöre grid during hauls at 3.0-3.2 knots

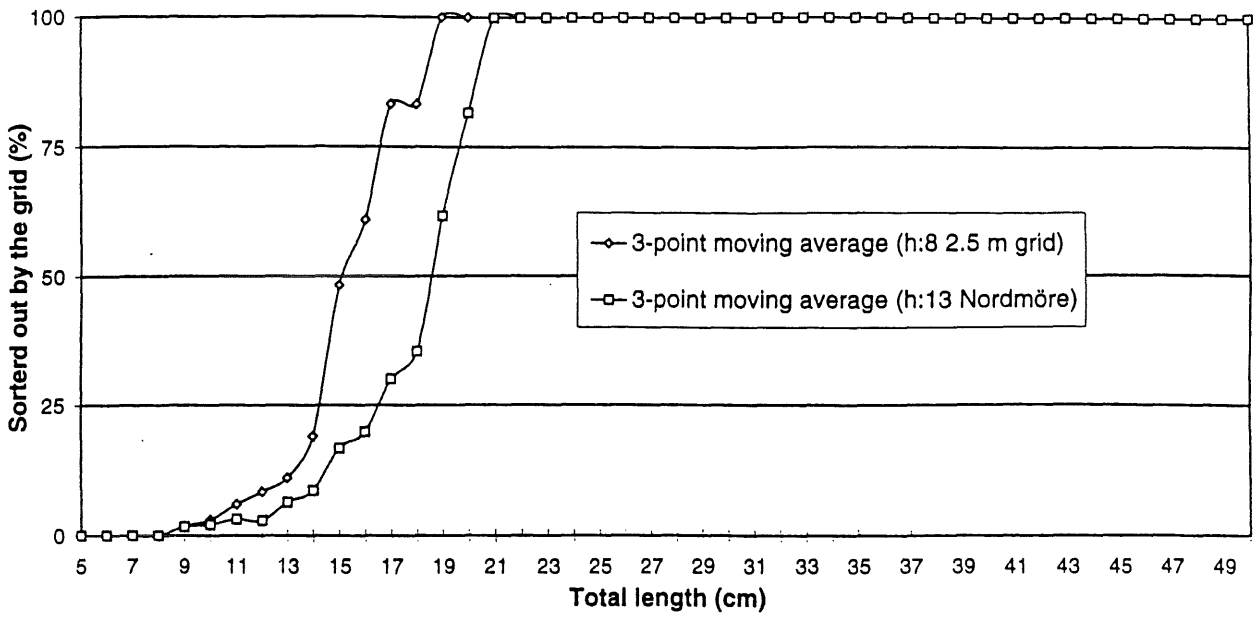


Fig. 3.3. Seleksjonskurver for torsk med ny type rist (2.5 m lang) og standard Nordmøre rist. Januar/februar 1996.

R.B. Larsen, NFH-UiTø, 1996

Sorting effect on red-fish (*Sebastes marinus*) with the new 2.5 m grid and the standard 1.5 m Nordmöre grid during hauls at 3.0-3.2 knots.

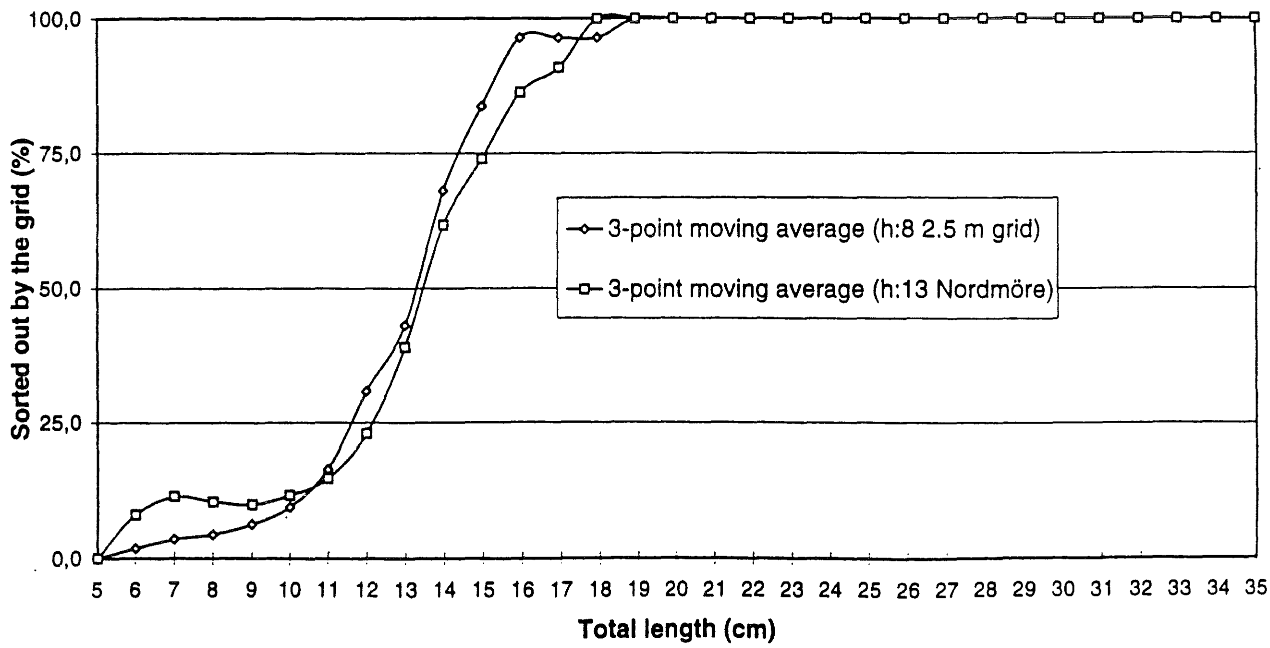


Fig. 3.4 Seleksjonskurver for uer (*S. marinus*) med ny type rist (2.5 m lang) og standard Nordmøre rist. Januar/februar 1996.

Sorting effect on Greenland halibut (*Reinhardtius hippoglossoides*) with the new 2.5 m grid and the standard 1.5 m Nordmöre grid during hauls at 3.0-3.2 knots.

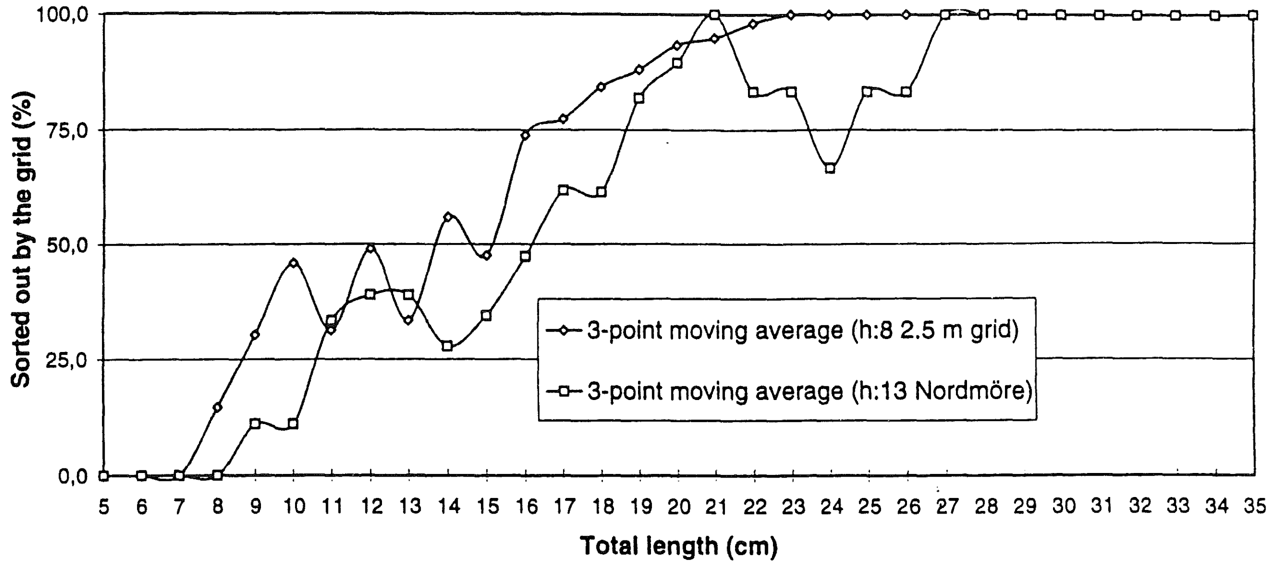


Fig. 3.5. Seleksjonskurver for blåkveite med ny type rist (2.5 m lang) og standard Nordmøre rist. Januar/februar 1996.

Sorting effect on Long rough dab (*Hippoglossoides platessoides*) with the new 2.5 m grid and the standard 1.5 m Nordmöre grid during hauls at 3.0-3.2 knots.

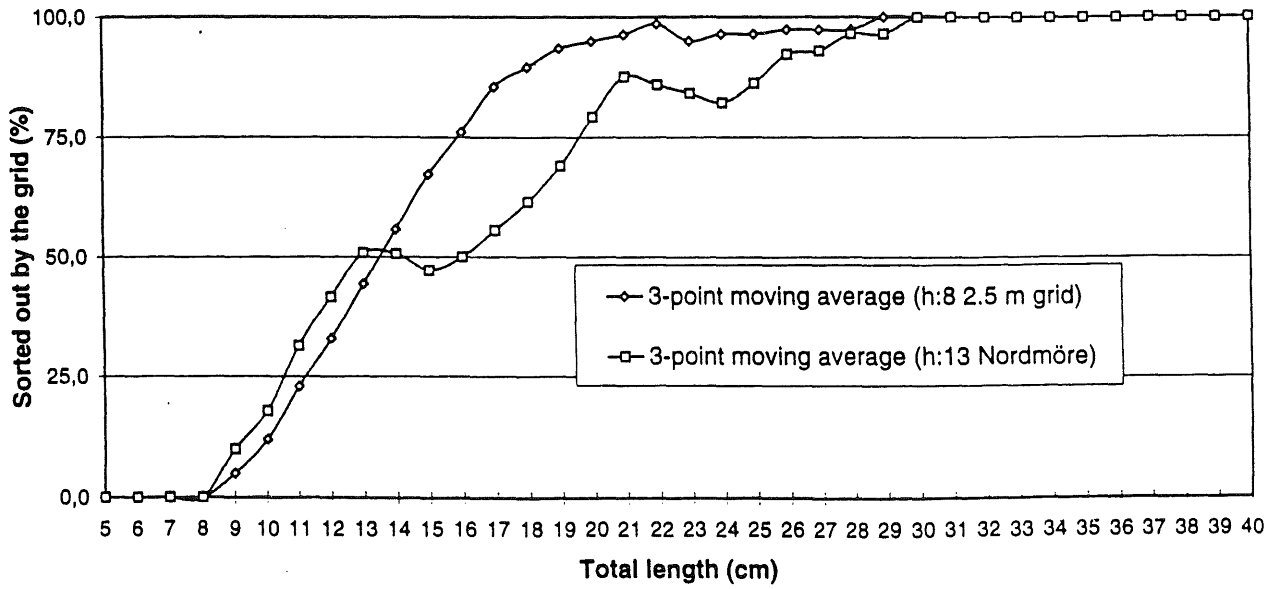


Fig 3.6. Seleksjonskurver for gapeflyndre med ny type rist (2.5 m lang) og standard Nordmøre rist. Januar/februar 1996.

APPENDIX VI

Valdemarsen et al.
Experiments on size-selectivity for Norway lobster using sorting grids in the aft trawl belly.

International Council for the
Exploration of the Sea

Grid (Grate) Study Group
Woods Hole, Massachusetts, April 1996

Experiments on size-selectivity for Norway lobster using sorting grids in the aft trawl belly

John Willy Valdemarsen, Institute of Marine Research, Bergen, Norway
Mats Ulmestrand, Institute of Marine Research, Lysekil, Sweden
Charles W. West, Institute of Marine Research, Bergen, Norway

Introduction

The coastal trawl fishery for Norway lobster (*Nephrops norvegicus* L.) has become increasingly important in the Skagerrak and Kattegat during the last decade. This fishery is currently regulated with a minimum codend mesh size of 70 mm. Routine measurements of the size distribution of Nephrops in commercial catches have shown that a large proportion of the catch (57% by weight, 78% in numbers) is below minimum landing size (MLS) and must consequently be discarded (Figure 1).

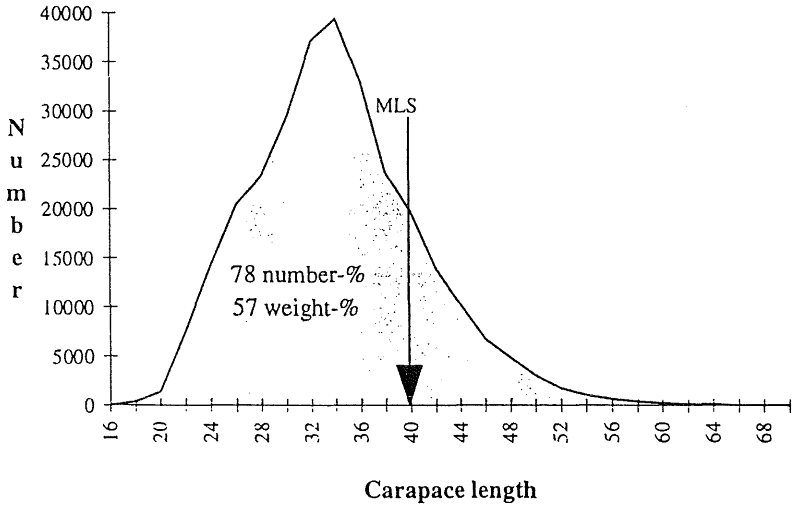


Figure 1. Average size composition of trawl-caught Nephrops during 1990-1994

In order to reduce the amount of undersized Nephrops in the catch, attempts have been made to improve size selectivity by constructing entire codends out of square mesh netting (Larsvik & Ulmestrand, 1992). The selection range for the square mesh codends tested was found to be as large as for typical diamond mesh codends, so to effectively achieve a reduction in the bycatch of undersized Nephrops would most probably cause an undesireable loss in landings of legal-sized Nephrops.

With the goal of developing a size selective device with a smaller selection range compared to square meshes, experiments were carried out using different grids inside the extension piece of a Nephrops trawl in a program of cooperative research involving scientists from Norway and Sweden.

Materials and methods

The experiments were conducted in the Skagerrak area and on the Egersunds Bank in the North Sea during May-June in each of three successive years (1993, 1994 and 1995). The Norwegian research vessel "Michael Sars" 45.7 m l.o.a. with a 1500 Hp engine was the platform for the trials.

The grid arrangement used in 1993 consisted of two equal grids, 1 m long and 1 m wide made from aluminium pipes (frame) and rods (bars) hinged together in tandem orientation. The inter-bar distances were on average 22.4 mm. The grids were arranged in a cylindrical section as illustrated in Figure 2 in one of two twin trawls. The organisms escaping through the grid were collected in a bag (mesh size 35 mm) mounted outside the grid. The main codend was also equipped with an inner liner of 35 mm meshes. In the analysis of the grid selectivity, only data from the trawl equipped with the grid was utilized. The grid sloped at a 30 degree angle aft and downward from the top panel. The bottom panel below the front attachment of the grid was lengthened by three meshes and lifted with two 8-inch floats. The netting below the rear part of the grid was also lengthened by two meshes to allow some additional space for organisms passing beneath the grid.

In 1994 the arrangement was similar to that in 1993 but with grids of 21.7 mm interbar spacing made from rods of glass reinforced plastic installed within a frame constructed of stainless steel pipe. The arrangement was installed in either one of the side trawls or in the center trawl of a triple trawl rigged as illustrated in Figure 3.

In the 1995 experiments a single grid sloping upwards 30 degrees (Figure 4) was tested in the center trawl of the triple trawl system. This arrangement's size selectivity performance for Nephrops was tested in 18 hauls. The main codend was equipped with an inner liner of 35 mm netting and a 35 mm collecting bag was mounted to the rear end of the guiding panel behind the grid. Three hauls were also taken with the metal grid (22.4 mm interbar spacing) arranged in the same manner as the plastic grid, mounted in the center trawl. The starboard trawl was always equipped with a normal codend with a 35 mm liner. The selectivity performance of both grids could thus be evaluated using the CC-Selectivity program (logit model), either by the covered-codend technique or by the trouser trawl technique.

Results

Table 1. Description of investigated grid type, test method, split factor (estimated or fixed), number of valid hauls, and selection parameters.

Grid type (mm dist.±SE)	Method	Split	Position Mounted	N hauls	L25 (mm)	L50 (mm)	95% CI min-max	SF	SR (mm)	95% CI min-max
Metal (22.4±0.12 mm)	Cover		in roof: \	10	30,8	37,2	36,6-37,7	1,653	12,8	11,3-14,3
Metal (22.4±0.12 mm)	Cover		in bottom: /	2	30,6	34,8	33,7-35,6	1,554	8,4	6,8-10,0
Metal (22.4±0.12 mm)	Triple trawl	Fixed 0.5	in bottom: /	2	34,8	40,4	38,6-43,4	1,804	11,2	6,9-15,4
Metal (22.4±0.12 mm)	Triple trawl	Est. 0.521	in bottom: /	2	34,0	38,5	35,0-51,4	1,719	7,8	3,2-14,7
Composite (21.7±0.05 mm)	Cover		in roof: \	8	26,7	33,7	31,7-35,2	1,532	13,9	9,6-18,3
Composite (21.7±0.05 mm)	Cover		in bottom: /	18	27,2	31,4	30,6-32,0	1,447	8,4	7,4-9,4
Composite (21.7±0.05 mm)	Triple trawl	Fixed 0.5	in bottom: /	14	29,6	36,9	35,8-38,1	1,700	14,5	11,2-17,8
Composite (21.7±0.05 mm)	Triple trawl	Est. 0.425	in bottom: /	5	30,0	33,9	32,5-35,8	1,562	7,8	5,9-9,9

The Nephrops grid selectivity results are presented in Table 1. During rough weather conditions the all-metal grid was found to be sensitive to physical damage leading to changes in the inter-bar distance, thus potentially causing an increase in selection range. This consideration compelled the use of the composite grid in the later experiments.

Since the grid was mounted in the center trawl in the triple-trawl experiments, and Nephrops catch rates (kg/hr) were usually lower in the center trawl than in the outer trawls, calculations of selection parameters using estimated split values were carried out when using the trouser model. Using this mode of analysis, it was only possible to obtain estimates for 5 of the 18 hauls with the composite material grid, whereas if the split value was fixed at 0.5 solutions could be obtained for 14 of the 18 hauls.

The results from this investigation indicate that L50 was about 4 mm higher for the 22.4 mm metal grid compared to the 21.7 mm composite material grid. For each grid type, estimated L50 values were essentially the same, whether top-mounted or bottom-mounted. The estimated L50 values obtained with the triple trawl (trouser model) technique were higher than those obtained with the covered-codend model.

Although the variation in selection range may be high, the covered-codend technique showed that a change of grid position from roof-mounted to bottom-mounted reduced the selection range for both the all-metal grid and the composite grid by 34% and 40% respectively. Similar results were obtained using the trouser trawl technique when split factors were estimated.

Discussion

Regardless of the selectivity estimation technique used (covered-codend versus trouser trawl), the main conclusion drawn from this investigation is that the selection range could be reduced for either grid type by mounting the grid in the trawl bottom, angled upwards and aftwards, compared to the selection range obtained when the grid was mounted in the roof. According to the covered-codend results, there was a tendency towards slightly lower L50 values for the bottom-mounted grid.

In light of the catch results showing that split values were never equal to 50%, using this fixed value may be inappropriate for the trouser trawl analysis, and greater confidence should be placed in selectivity parameter estimates obtained when the split values were estimated.

There are several possible explanations for the higher Nephrops L50 values obtained using the trouser model versus the covered-codend model. We feel that these can be ranked in the following order of descending likelihood:

1) The grid's rigid frame may have forced open the meshes surrounding it in the extension section, allowing escapement of smaller individuals that never encountered the grid itself. Accordingly the Nephrops subjected to the grid's sorting effect would have already been "pre-sorted" to some extent. Such mesh selection would not occur in the standard extension piece and codend used as the basis for comparison in the trouser trawl analysis. For the covered-codend technique to adequately accommodate this additional escapement, it would have been

necessary for the cover to surround the entire section within which the grid was installed instead of simply collecting the individuals sorted out by the grid.

2) The set of hauls for which a solution could successfully be obtained using the trouser analysis was different from the data set for the covered-codend technique, so haul-to-haul variability may have affected the results.

3) There may have been some sort of "masking" effect due to the presence of the cover, as is commonly reported when comparing selectivity estimates derived from covered-codend results versus other techniques. However, due to the design of the cover and what is known about Nephrops behaviour patterns this does not seem to be a likely explanation.

References

Larsvik, M. & L. Ulmestrand, 1992. Square and diamond mesh trawl codend selection on *Nephrops norvegicus* (L.), analysed with the curve-fit method of isotonic regression. ICES C.M. 1992/B:36. 1-11+ appendix 1-6.

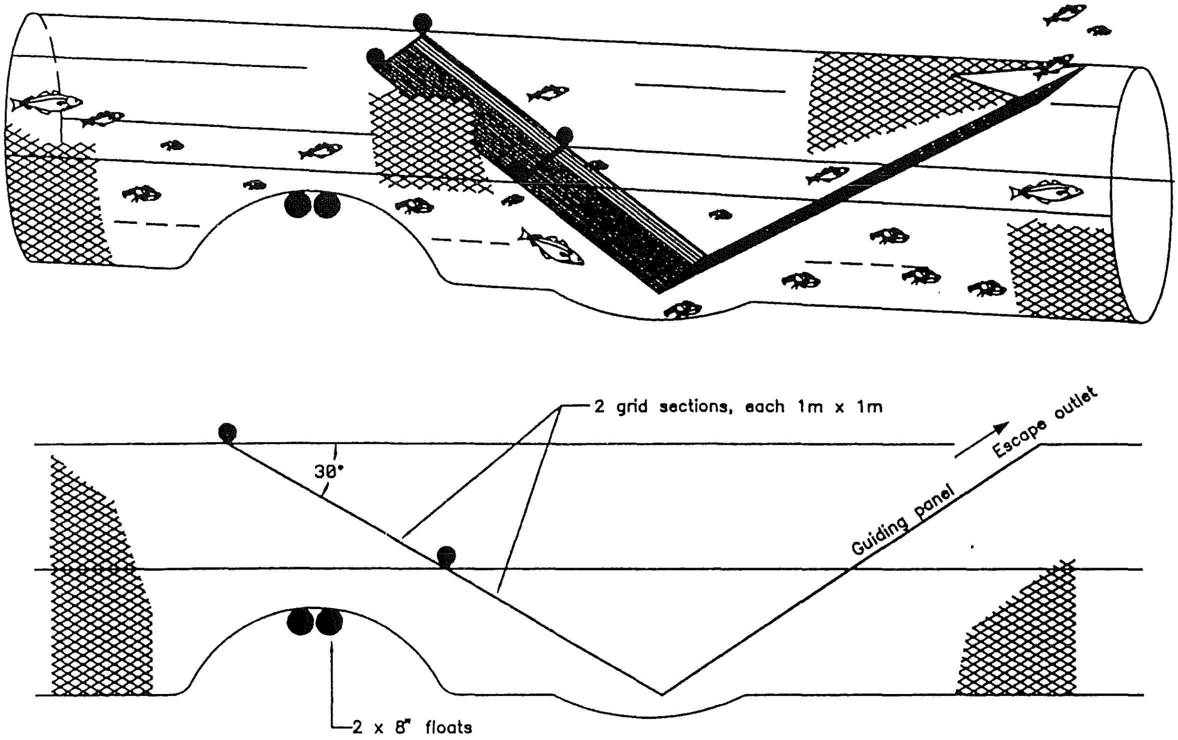


Figure 2. Roof-mounted grid & extension

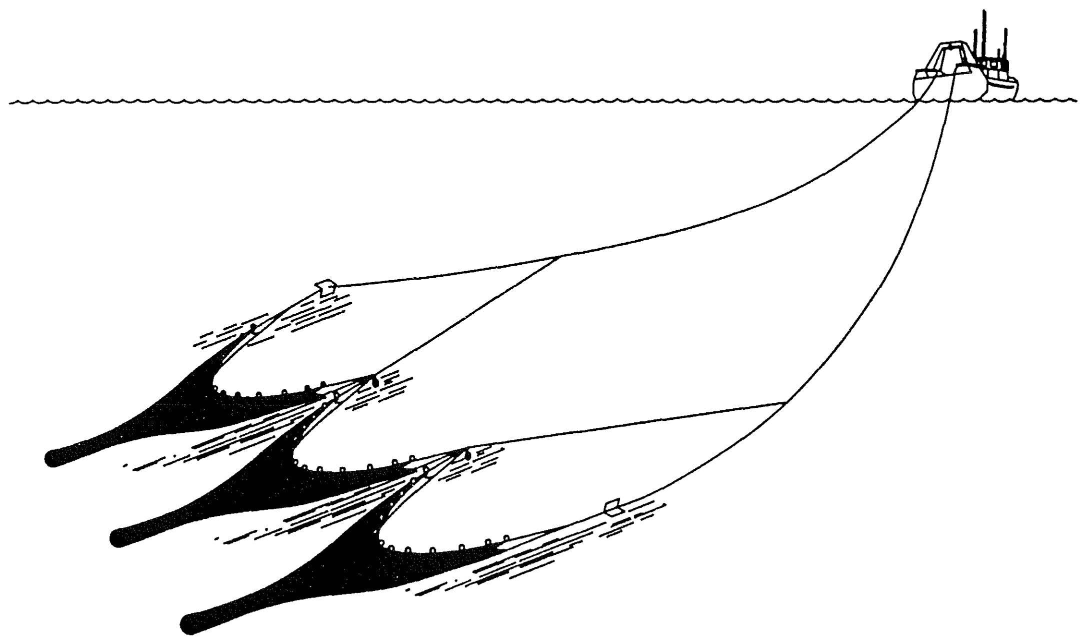


Figure 3. Schematic of triple trawl system

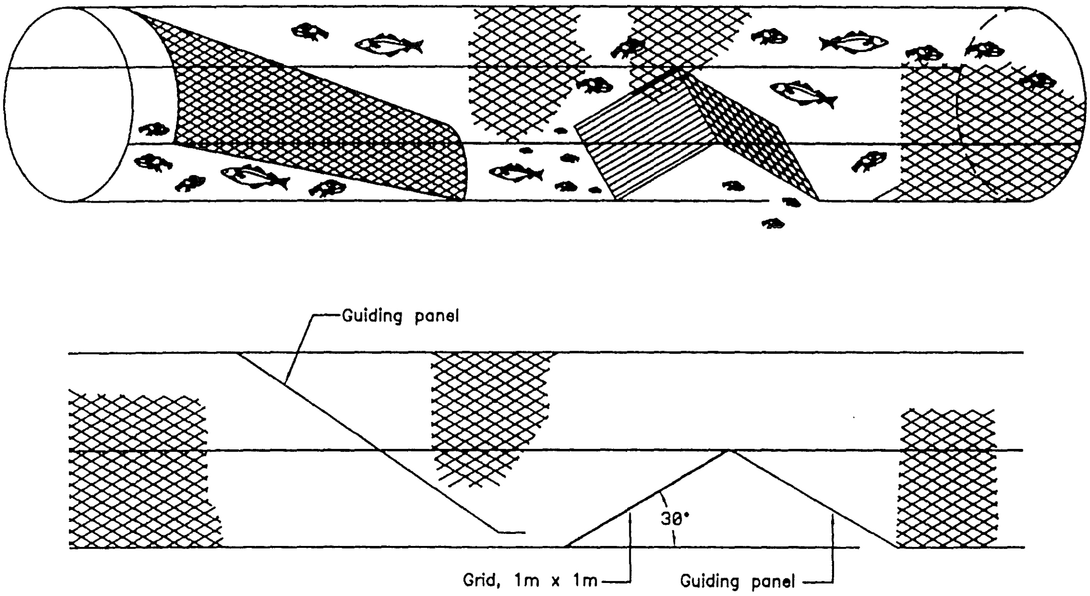


Figure 4. Bottom-mounted grid & extension